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TYPE MATERIAL OF THE SPECIES OF CLERID BEETLES DESCRIBED BY CHARLES SCHAEFFER

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TYPE MATERIAL OF THE SPECIES OF CLERID BEETLES DESCRIBED BY CHARLES SCHAEFFER

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Between 1904 and 1921, while acting as curator of entomology of the Museum of the Brooklyn Institute of Arts and Sciences, Charles Schaeffer described 45 new species of beetles of the family Cleridae from America north of Mexico. Only in his 1921 paper on the genus *Aulicus* did he designate a single specimen as type of a species. In his early works he selected up to six specimens to stand as types of a species, and later he made no mention of the number of specimens before him upon which the description of a species was based. Occasionally it is possible for the reader to tell that one, or more than one, specimen was involved, from the remarks that follow the description.

Mr. Schaeffer's type material was originally deposited in four different collections: the collection of the Museum of the Brooklyn Institute (33 species); the Schaeffer collection, in which is incorporated the Ottomar Dietz collection (7 species); the United States National Museum (4 species); and the H. F. Wickham collection (1 species). All these collections are now in the National Museum and therefore all, or almost all, the type material is there. The writer has recently studied all this material and has designated lectotypes for all species except where the original description and discussion indicate that no more than one specimen was before the describer.

It has not been possible to recognize the type specimen of *Hydnocera nunnenmacheri* Schf. This species was described in 1908 from a single specimen bearing the same data as that given for the type material of *Hydnocera fuchsi* Schf. (described on the preceding page of the same work). In 1917 Mr. Schaeffer suppressed the former as a synonym of the latter. No specimen bearing the name label "Hydnocera nunnenmacheri" is to be found either in the collection of the Brooklyn Institute or in the Schaeffer collection. It is possible that upon recognizing the synonymy, Mr. Schaeffer returned the type of *H. nunnenmacheri,* minus its distinguishing label, to the type series of *H. fuchsi.*

It will be noted further on in this paper that often the type locality of a species is given as "Huachuca Mts., Arizona," and the data for the lectotype as "Palmerlee, Cochise Co., Arizona." It should be explained that Mr. Schaeffer made his headquarters for the Huachuca Mountains trip at Palmerlee and that he used the more exact locality data on the specimens themselves.

It might here be mentioned that twice Mr. Schaeffer introduced names into the literature through error. His *Clerus bioculatus* (1905, Mus. Brooklyn Inst., Sci. Bull., vol. 1, p. 154) is certainly a lapsus for *Clerus bimaculatus* Skinner, and his "var. *rufulus*" (1917, Journ. New York Ent. Soc., vol. 25, p. 131) is apparently an earlier choice of name for the variety that he described under the name of *Clerus rosmarus* var. *virginiensis*.

In the following list the species are arranged alphabetically by specific name without regard to the genus in which each was described. The generic name of the original combination follows the specific name. No attempt has been made to show the present generic assignment of any of the species.

antennata, Cymatodera
1908. Journ. New York Ent. Soc., vol. 16, p. 128.

Type locality—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens. Both sexes described. Three specimens, including one male, each bearing the label TYPE in the Brooklyn Museum collection; three additional specimens, without TYPE labels, in the Schaeffer collection.

Lectotype.—The male bearing Schaeffer's TYPE label, with the more detailed locality data Palmerlee, Cochise Co., Ariz., Aug. 17. U.S.N.M. No. 42533.

antennatus, Aulicus
1921. Proc. U. S. Nat Mus., vol. 59, p. 158.

Type locality.—Palm Springs, California.

Type series.—"The male (type) is in the collection of Professor Wickham and the female (allotype) in the collection of the Brooklyn Museum."

Holotype.—The male specimen from the Wickham collection, U.S.N.M. No. 50191.

arizonica, Cymatodera undulata var.
1908. Journ. New York Ent. Soc., vol. 16, p. 130.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. A

male, labeled TYPE by Schaeffer, and a female, both from Palmerlee, Cochise Co., Ariz., in the Brooklyn Museum collection. A male from Huachuca Mts., Ariz., in the Schaeffer collection.

Lectotype.—The male, labeled as TYPE by Schaeffer. Its label carries the date June 24. U.S.N.M. No. 42537.

arizonica, Hydnocera
1908. Journ. New York Ent Soc., vol. 16, p. 132.

Type locality.—Huachuca Mts., Arizona.

Type series.—"In the two type specimens, male and female, * · ." In addition to two specimens labeled TYPE by Schaeffer, there are 15 additional specimens in the Brooklyn Museum collection.

Lectotype.—The male bearing the TYPE label, U.S.N.M. No. 42540.

brevicollis, Cymatodera
1917. Journ. New York Ent. Soc., vol 25, p. 130.

Type locality.—Arizona.

Type series.—"The single specimen, a female, was placed in the Dietz collection with *ovipennis,* which it superficially very much resembles."

Holotype.—The above-described specimen in the Schaeffer collection. U.S.N.M. No. 59058.

cephalica, Cymatodera
1908. Journ. New York Ent. Soc., vol. 16, p. 130.

Type locality.—El Taste and Santa Rosa, Lower California.

Type series.—" * * * , collected by Mr. Gustav Beyer, to whom I am indebted for the pair."

Lectotype.—The male from the above-mentioned pair, from El Taste, in the Brooklyn Museum collection. U.S.N.M. No. 42538.

dentipes, Aulicus
1921. Proc. U. S. Nat. Mus., vol. 59, p. 157.

Type locality.—San Diego, Texas.

Type series.—Type (male), allotype and paratypes designated in the original publication.

Holotype.—U.S.N.M. No. 23085.

femoralis, Aulicus
1917. Journ. New York Ent. Soc., vol. 25, p. 132.

Type locality.—Nogales, Arizona.

Type series.—No indication of number of specimens or sex. Two

specimens, male and female, collected at the designated type locality by F. W. Nunnenmacher, in the Brooklyn Museum collection.

Lectotype.—The above-mentioned male, U.S.N.M. No. 42547.

fissipes, Aulicus

1921. Proc. U. S. Nat. Mus, vol 59, p. 155.

Type locality.—Tucson, Arizona.

Type series.—Type (male) and allotype (female) designated in the original publication.

Holotype.—U.S.N.M. No. 23083.

flavosignata, Cymatodera

1908. Journ. New York Ent. Soc., vol. 16, p. 129

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens. Both sexes described. Six specimens in the Brooklyn Museum collection and three additional in the Schaeffer collection, all labeled Palmerlee, Cochise Co., Arizona.

Lectotype.—A male from the series in the Brooklyn Museum collection, collected on Aug. 18. U.S.N.M. No. 42535.

floridana, Chariessa

1917. Journ. New York Ent. Soc., vol. 25, p. 133.

Type locality.—Key Largo, Florida.

Type series.—"The type specimen, a female, was collected and given me by Mr. G. Beyer." No mention of further material is made but Mr. Schaeffer, in 1918, presented the writer with a specimen, also a female, with identical data.

Lectotype.—The female in the Schaeffer collection. U.S.N.M. No. 59059.

fuchsi, Cymatodera

1904. Journ. New York Ent. Soc., vol. 12, p 216.

Type locality.—Texas.

Type series.—"One male in my possession kindly given to me a few years ago by Mr. Chas. Fuchs * * * ."

Holotype.—A male specimen from Texas, in the Brooklyn Museum collection, bearing Mr. Schaeffer's TYPE label. U.S.N.M. No. 42519.

fuchsi, Hydnocera

1908. Journ. New York Ent. Soc., vol. 16, p. 132.

Type locality.—Nogales, Arizona.

Type series.—No indication of number of specimens or sex. One

specimen, apparently a male, labeled TYPE in the Brooklyn Museum collection; six specimens, males and females, in the Schaeffer collection.

Lectotype.—The specimen bearing the TYPE label, in the Brooklyn Museum collection. U.S.N.M. No. 42539.

furcatus, Colyphus

1904. Journ. New York Ent. Soc., vol. 12, p. 218.

Type locality.—Brownsville, Texas (San Tomas, Esperanza Ranch).

Type series.—"Four specimens in collection of the Museum of the Brooklyn Institute of Arts and Sciences." Four specimens labeled TYPE and eight others in the Brooklyn Museum collection and three in the Schaeffer collection.

Lectotype.—A male, one of the four bearing TYPE label, mentioned above. U.S.N.M. No. 42521.

granulatipenne, Enaplium (sic!)

1904. Journ. New York Ent. Soc., vol. 12, p. 220

Type locality.—Brownsville, Texas (Los Boragos).

Type series.—"Types, six specimens in the Museum of the Brooklyn Institute." As there are in all eight specimens from Los Boragos in that collection, it is not possible to distinguish the six referred to in the original publication. Schaeffer had placed TYPE labels on two specimens, a male and a female.

Lectotype.—The male, selected by Schaeffer, mentioned above. U.S.N.M. No. 42525.

humeralis, Clerus

1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 155.

Type locality.—Tulare Co., California.

Type series.—" * * *, two specimens in the collection Dietz." One specimen, apparently a female, labeled TYPE by Schaeffer, in the Brooklyn Museum collection; another specimen, also apparently female, in the Schaeffer collection.

Lectotype.—The specimen labeled as TYPE by Schaeffer, U.S.N.M. No. 42531.

laevicollis, Cymatodera

1908. Journ. New York Ent. Soc., vol. 16, p. 130

Type locality.—Huachuca Mts., Arizona.

Type series.—"One female." A female specimen, without locality

label, is in the Brooklyn Museum collection. It bears the following labels: (1) TYPE; (2) Catal. No. 563; (3) Cymatodera laevicollis Schaef.

Holotype.—The above-described female specimen. U.S.N.M. No. 42536.

latefascia, Cymatodera

1904. Journ. New York Ent. Soc., vol. 12, p. 216.

Type locality.—Fort Grant, Arizona; New Mexico.

Type series.—"Three specimens; a female in the [U. S. National] Museum collection from the first named locality, kindly given by Mr. Schwarz, another female from New Mexico and a male from Arizona without definite locality. Type No. 8163, U. S. National Museum."

Holotype.—The specimen from Fort Grant, Ariz. U.S.N.M. No. 8163.

maculicolle, Pelonium

1904. Journ. New York Ent. Soc., vol. 12, p. 219

Type locality.—Brownsville, Texas.

Type series.—"Four specimens in the Museum of the Brooklyn Institute." Three males and one female, each labeled TYPE, in the Brooklyn Museum collection.

Lectotype.—A male from the above-mentioned series. U.S.N.M. No. 42524.

mesosternalis, Lebasiella

1908. Journ. New York Ent. Soc., vol. 16, p. 135.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. One specimen, labeled TYPE by Schaeffer, in the Brooklyn Museum collection; a second, without type label, in the Schaeffer collection.

Lectotype.—The specimen, apparently a female, in the Brooklyn collection. U.S.N.M. No. 42543.

nigrescens, Enoplium

1904. Journ. New York Ent. Soc., vol. 12, p. 221.

Type locality.—Brownsville, Texas (Esperanza Ranch).

Type series.—"One specimen in the Museum of the Brooklyn Institute."

Holotype.—The above-mentioned specimen, a male, U.S.N.M. No. 42526.

nigrescens, Hydnocera
1909. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 15, p. 381.

Type locality.—Southern Pines, North Carolina.

Type series.—No indication of number of specimen or sex. One specimen in Brooklyn Museum collection collected May 21, 1907, and two specimens in the Schaeffer collection taken May 30, 1912, and May 17, 1915, all from Southern Pines by A. H. Manee.

Lectotype.—[Probably holotype], the specimen, a female, collected May 21, 1907, in the Brooklyn Museum collection. U.S.N.M. No. 42544.

nigrina, Hydnocera
1908. Journ. New York Ent. Soc., vol. 16, p. 134.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. A single specimen in the Brooklyn Museum collection from Carr's Peak, Huachuca Mts., Ariz., July 20, and labeled TYPE by Schaeffer.

Lectotype.—[Probably holotype], the above-described specimen, apparently a female. U.S.N.M. No. 42542.

nigriventris, Aulicus
1921. Proc. U. S. Nat. Mus., vol. 59, p. 156.

Type locality.—Mexico.

Type series.—Type (male), allotype (female) and paratypes, designated in the original publication.

Holotype.—U.S.N.M. No. 23084.

niveifascia, Hydnocera
1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 156.

Type locality.—Palmerlee, Cochise Co., Arizona.

Type series.—No indication of number of specimens or sex. Eight specimens, all from the designated type locality, in the Brooklyn Museum collection. One specimen was labeled TYPE by Schaeffer.

Lectotype.—The specimen labeled TYPE by Schaeffer, apparently a male, U.S.N.M. No. 42532.

nunnenmacheri, Hydnocera
1908. Journ. New York Ent. Soc., vol. 16, p. 133.

Type locality.—Nogales, Arizona.

Type series—" * * * , one male kindly given me by Mr. F. W.

Nunnenmacher." No specimen bearing this name was found either in the Brooklyn Museum collection or in the Schaeffer collection.

Holotype.—Lost. See introductory remarks for discussion.

obliquefasciata, Cymatodera

1904. Journ. New York Ent. Soc., vol. 12, p. 215.

Type locality.—Brownsville, Texas (Esperanza Ranch), from *Acacia flexicaulis.*

Type series.—"Three specimens in the Museum of the Brooklyn Institute." Four specimens in the Brooklyn Museum collection, three of which, a male and two females, bear Schaeffer's TYPE label.

Lectotype.—The male, from the above-mentioned series. U.S.N.M. No. 42517.

pallida, Cymatodera

1908. Journ. New York Ent. Soc., vol. 16, p. 128.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens. Both sexes described. Four specimens, two males, one female, and one of uncertain sex, in the Brooklyn Museum collection; one female in the Schaeffer collection.

Lectotype.—A male in the Brooklyn Museum collection. U.S.N.M. No. 42518.

pallipes, Macrotelus terminatus var.

1908. Journ. New York Ent. Soc., vol. 16, p. 128.

Type locality.—Brownsville, Texas.

Type series.—"The moderately large series which I have taken or raised from branches of *Acacia farnesiana* and *Acacia flexicaulis* * * * ." Four specimens, two males and two females, in the Brooklyn Museum collection and four in the Schaeffer collection.

Lectotype.—A male from the series in the Brooklyn Museum collection, U.S.N.M. No. 42534.

palmii, Clerus

1904. Journ. New York Ent. Soc., vol. 12, p. 218.

Type locality.—Senator, Arizona.

Type series.—"One specimen kindly given to me some years ago by Mr. Chas. Palm * * * ."

Holotype.—The specimen in the Brooklyn Museum collection from the designated type locality. U.S.N.M. No. 42522.

parviceps, Hydnocera
1908. Journ. New York Ent. Soc., vol. 16, p. 134.

Type locality.—Senator, Arizona.

Type series.—"One female given me some years ago by Mr. Charles Palm." One specimen in the Schaeffer collection.

Holotype.—The above-mentioned female specimen. U.S.N.M. No. 59066.

peninsularis, Cregya
1917. Journ. New York Ent. Soc., vol. 25, p. 132.

Type locality.—Santa Rosa, Lower California.

Type series.—No indication of number of specimens or sex. One female in the Brooklyn Museum collection and a pair, male and female, in the Schaeffer collection, all from Santa Rosa.

Lectotype.—The male specimen from the Schaeffer collection. U.S.N.M. No. 42548.

peninsularis, Cymatodera
1904. Journ. New York Ent. Soc., vol. 12, p. 214.

Type locality.—San Felipe, Lower California.

Type series.—"Two specimens from Mr. G. Beyer in the Museum of the Brooklyn Institute." Both specimens are male.

Lectotype.—One of the two above-mentioned specimens. U.S.N.M. No. 42516.

pinus, Clerus
1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 155.

Type locality.—"Carr's Peak, Huachuca Mountains, Arizona, beaten from pines at an elevation of 9,000 feet."

Type series.—No indication of number of specimens or sex. Two specimens from Carr's Peak, one bearing Schaeffer's TYPE label, in the Brooklyn Museum collection.

Lectotype.—A male, bearing Schaeffer's TYPE label. U.S.N.M. No. 42530.

pusilla, Hydnocera
1909. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 15, p. 381.

Type locality.—Nogales, Arizona.

Type series.—No indication of number of specimens or sex. Three specimens, each labeled TYPE by Schaeffer, in the Brooklyn Museum collection. Three, without such labels, in the Schaeffer collection.

Lectotype.—A male, one of the three specimens in the Brooklyn Museum collection. U.S.N.M. No. 42545.

quercus, Clerus
1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 154.

Type locality.—Palmerlee, Cochise Co., Arizona, from oak.

Type series.—No indication of number of specimens or sex. A single specimen, a male, from the designated type locality, bearing Schaeffer's TYPE label, in the Brooklyn Museum collection.

Lectotype.—[Probably holotype], the above-mentioned specimen. U.S.N.M. No. 42529.

ruficollis, Monophylla
1911. Journ. New York Ent. Soc., vol. 19, p. 121.

Type locality.—Arizona.

Type series.—" * * * , the single specimen, a female in my collection, * * * ."

Holotype.—A female from Arizona, in the Schaeffer collection. U.S.N.M. No. 59060.

santarosae, Cymatodera
1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 152.

Type locality.—Santa Rosa, Lower California.

Type series.—" * * * , male and female, collected by Mr. Gustav Beyer, to whom I am indebted for the pair." A pair in the Brooklyn Museum collection, which were labeled TYPE ♂ and TYPE ♀ by Schaeffer.

Lectotype.—The male from the above-mentioned pair. U.S.N.M. No. 42528.

simulans, Hydnocera
1908. Journ. New York Ent. Soc., vol. 16, p. 133.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. One specimen labeled TYPE by Schaeffer, in the Brooklyn Museum collection, together with three others, all from the designated type locality.

Lectotype.—The specimen labeled TYPE by Schaeffer. U.S.N.M. No. 42541.

subcostatus, Clerus thoracicus var.
1917. Journ. New York Ent. Soc., vol. 25, p. 131.

Type locality.—Enterprise, Florida.

Type series.—"Enterprise, Florida (O. Dietz). I have another specimen from New Braunfels, Texas, which agrees with the Florida specimen in the characters given above."

Lectotype.—The Enterprise, Fla., specimen, in the Schaeffer Collection. U.S.N.M. No. 59061.

tricolor, Hydnocera
1904. Journ. New York Ent. Soc., vol. 12, p. 219.

Type locality.—Brownsville, Texas.

Type series.—"Four specimens in the Museum of the Brooklyn Institute." Of these, one is a male, the other three are females.

Lectotype.—The male from the above-mentioned series. U.S.N.M. No. 42523.

tristis, Hydnocera
1909. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 15, p. 381.

Type locality.—Huachuca Mts., Arizona.

Type series.—No indication of number of specimens or sex. A single specimen, a male, labeled TYPE by Schaeffer, in the Brooklyn Museum collection. A second specimen in Schaeffer collection.

Lectotype.—The male in the Brooklyn Museum collection. U.S.N.M. No. 42546.

uniformis, Cymatodera
1905. Mus. Brooklyn Inst., Sci. Bull., vol. 1, No. 7, p. 151.

Type locality.—Prescott, Arizona.

Type series.—" * * * , one male, which I owe to the kindness of Mr. Charles Fuchs, of San Francisco, Cal."

Holotype.—The above-mentioned specimen, in the Brooklyn Museum collection. U.S.N.M. No. 42527.

van dykei, Cymatodera
1904. Journ. New York Ent. Soc., vol. 12, p. 217.

Type locality.—California (Los Angeles Co.).

Type series.—"Two specimens kindly given to me by Dr. Van Dyke to whom this species is dedicated." A male and a female, each labeled TYPE by Schaeffer and both in the Brooklyn Museum collection.

Lectotype.—The male specimen mentioned above. U.S.N.M. No. 42520.

virginiensis, Clerus rosmarus var.
1917. Journ. New York Ent. Soc., vol. 25, p. 131.

Type locality.—Virginia.

Type series.—No indication of number of specimens or sex. A single specimen in the Schaeffer collection.

Lectotype.—The above-mentioned specimen. U.S.N.M. No. 59062.

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Thomas Lincoln Casey Fund

LARVAE OF THE ELATERID BEETLES OF THE TRIBE LEPTUROIDINI (COLEOPTERA: ELATERIDAE)

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LARVAE OF THE ELATERID BEETLES OF THE TRIBE LEPTUROIDINI (COLEOPTERA: ELATERIDAE)

By ROBERT GLEN[1]

Research Coordinator, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada

INTRODUCTION

Characters for the identification of species are sadly lacking for most of the larval Elateridae. This lack of fundamental information is not surprising because most elaterid larvae are difficult to find and they require several years to mature. The task of collecting and rearing them is so great that only a small proportion of the species is known in the larval stage, and progress in larval taxonomy has been handicapped constantly by insufficient representation to characterize the genera. This is particularly true of the Lepturoidini, which includes important crop pests throughout the world, especially in western North America. Many of these pest species are now known to react differentially to factors of weather, soil, and culture, and the control program to be prescribed depends largely upon the species involved. Thus, accurate specific identification is the first need of the economic investigator.

It was largely to fill such a need that the present study arose. In 1922 K. M. King, Officer in Charge of the Dominion Entomological Laboratory, Saskatoon, Saskatchewan, initiated investigations upon wireworm control in the Prairie Provinces, and as an integral part of the project he included studies of larval morphology. He continued this work, as time permitted, until 1929 and succeeded in rearing several of the pest species and in obtaining characters for the separation of their larvae in the field. The author was then made responsible for the furtherance of this work, and in 1931 he prepared descriptions of the larvae of 18 Saskatchewan species. This experi-

[1] Formerly in charge Wireworm Investigations, Dominion Entomological Laboratory, Saskatoon, Saskatchewan.

ence, together with a study of the literature, convinced the writer that adequate generic and specific characters could not be drawn from an investigation limited to the Elateridae of Saskatchewan, or from superficial studies covering a larger region. Instead, he concluded that true generic and specific characters could be obtained only through an intensive comparative study involving all available species of the group under investigation.

The present study, which deals particularly with the genus *Ludius* Eschscholtz, is based upon these principles. In the broad sense it consists of two parts: a detailed treatment of all available identified *Ludius* larvae in the world, and a comprehensive survey of the larval morphology of the other genera included by Hyslop (1917) in the tribe Lepturoidini. The investigation was discontinued in 1942 and is believed to be a reasonably complete record and analysis of the pertinent information available at that time. Only mature or nearly mature larvae are considered. The 93 species included represent 11 genera as follows: *Athous* (14), *Crepidomenus* (1), *Cryptohypnus* (5), *Eanus* (2), *Elathous* (1), *Hemicrepidius* (5), *Hypnoidus* (3), *Lepturoides* (3), *Limonius* (14), *Ludius* (44), and *Melanactes* (1). It is essentially a study in detail and will be used most conveniently by workers who have a knowledge of the basic morphology of elaterid larvae as outlined by Glen, King, and Arnason (1943).

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All illustrations were prepared by the writer.

LITERATURE

The first important contribution to the morphology and biology of the larval Elateridae appeared in the last half of the nineteenth century when European workers took an evident interest in larval Coleoptera in general. Chapuis and Candeze (1855), Schiodte (1870), Perris (1863, 1877), Rupertsberger (1880, 1894), and Rey (1887) produced general works that included significant sections on the Elateridae. These paved the way for the comprehensive treatises of Beling (1883–1884) and Henriksen (1911), which were devoted entirely to elaterid larvae. With the advent of World War I, 1914–1918, and the consequent increased attention to agricultural production, there was a marked awakening of interest in the pest species. The identification of closely related forms was required, and broad generic studies gave way to detailed morphology. The results are revealed in the useful papers of Ford (1917), Roberts (1919, 1921, 1922, 1928), Horst (1922), Saalas (1923a, 1923b), Rambousek (1928), Guéniat (1934), Subklew (1934b), and the Australian worker McDougall (1934). An increased interest in biology brought forth the publications of Rambousek (1929) and the German writers Blunck (1925), Langenbuch (1932), and Subklew (1934b). Numerous Russian workers today are contributing valuable biological information in the reports of their faunal surveys and other ecological work.

In America the first important comparative morphology of wireworms originated in investigations of an economic character. The pioneers—Fitch (1867), Comstock and Slingerland (1891), and Forbes (1892)—limited their studies to pest species. Thereafter, interest centered upon control until Hyslop (1917) turned his attention to a study of the larval characters for the identification of the major subdivisions of the family. This work was slightly revised by Böving and Craighead (1931) in their general treatise on coleopterous larvae. The most recent work on comparative morphology has been done in Canada, where Glen (1931, unpublished thesis) distinguished the larvae of 18 species occurring in Saskatchewan, and later Glen, King, and Arnason (1943) worked out the identification of wireworms of economic importance in Canada. As in Europe, however, most of the recent studies have centered on detailed morphology as a basis for the identification of closely related species: Hyslop (1915b), Arnason (1931, unpublished thesis), Hyslop and Böving (1935), Glen (1935, 1941), Hawkins (1936), Jewett (1939), and Lanchester (1939, 1941). Economic entomologists have continued to contribute notes on the biology and ecology of the wire-

worm pests. The most important recent papers concerning species of the tribe Lepturoidini are those of Graf (1914), Hyslop (1915a), Lane (1925, 1931, 1935), King (1928), King, Arnason, and Glen (1933), Strickland (1935, 1939), Stone (1941), and Glen, King, and Arnason (1943).

The first century of work has merely introduced this field of research. Fine progress has been made toward the establishment of characters for subfamilies and for most of the tribes within them. In general, genera and species are poorly defined. This is true particularly of the tribe Lepturoidini, which has been incompletely studied in Europe and almost totally neglected in America. Most of the comparative morphology has been too superficial or too limited in scope to reveal the basic relationships. As a result, all available larval keys to genera and to species have little more than local value; they do not adequately define the genera and species that they include. However, a basis for better comparative work is resulting from the excellent detailed morpohological studies of recent years, and more adequate characterization of genera and species should be possible in the near future.

The outstanding taxonomic studies are those of Schiodte, Beling, Henriksen, and Hyslop, while the best work on morphology has been done by Roberts, Hyslop and Böving, and Lanchester. These contributions are discussed separately along with important contemporary works.

Schiodte, J. C., 1870: As a pioneer effort this is a most remarkable contribution and must be ranked among the classics of science. Broad, comparative, detailed studies are illustrated with well-selected figures, and conclusions are presented in a systematic conspectus. In some of his descriptions (e.g., *Alaus myops* (Fabricius), p. 500) and in certain figures the author achieves great excellence. However, many descriptions lack important details, and several figures overemphasize sculpture to a disturbing degree. In the systematic conspectus we find the first attempt to provide separating characters for genera and for related species. While this conspectus does not meet our needs today it served as a basis for progress and parts of it are fundamentally sound. The descriptions include 14 species of the tribe Lepturoidini, of which 6 are *Ludius,* but the genera of this tribe are not characterized. Horst (1922, p. 21) criticizes Schiodte, and with some justification, for not stipulating clearly the reliability of the identification of the material used.

Perris, Edouard, 1877: Very good larval descriptions are found in this work, but most of the illustrations are so small and sketchy

as to be practically worthless. Diagnostic specific characters are stressed, but only two species of *Ludius* are described. There is a key to genera, including several subgenera of *Ludius*, based largely upon the findings of Schiodte.

Beling, Th., 1883-1884: This author discusses 55 European species, 11 belonging to the genus *Ludius*, and a key to species is included. Larval and pupal descriptions are combined with excellent notes on habitat and on the occurrence and duration of the pupal period. On the whole, the descriptions are good and somewhat more detailed than those of Schiodte, but unfortunately no illustrations are given.

Comstock, J. H., and Slingerland, M. V., 1891: This bulletin includes illustrated descriptions of the larvae of five pest species belonging to five distinct genera, along with important notes on their life history. Although it is a pioneer American work the descriptions and figures are done with surprising detail, but many of the figures are smaller than desirable. It has served as a useful model in the progress of this work in America. The descriptions of the two lepturoidine larvae that are included—*Hemicrepidius hemipodus* (Say) (=*Asaphes decoloratus* Say) and *Cryptohypnus abbreviatus* (Say)—are as good as any descriptions yet made of these species, although certain important details are omitted.

Forbes, S. A., 1892: Nine pest species are included in this early American work, but the larvae of only six species are described and illustrated. No *Ludius* larvae are included. Only two of the descriptions are original, the others being taken verbatim from Comstock and Slingerland (1891). Both the descriptions and the figures are useful, although pertinent details are lacking. Of prime significance is the key to genera, which was the only key to elaterid larvae in the American literature until the recent publications of Van Zwaluwenburg (1939) and Glen, King, and Arnason (1943). Ten genera occurring in Illinois are separated, but the lepturoidine genera—*Athous*, *Ludius* (=*Corymbites*), *Hemicrepidius* (=*Asaphes*), and *Cryptohypnus*—are not distinguished. Important observations on bionomics are included.

Henriksen, K. L., 1911: Henriksen extended the work of his fellow countryman J. C. Schiodte. Although his studies are limited to the Danish Elateridae, he describes and illustrates 42 species. His conclusions are presented in several keys. His key to 18 genera separates, for the first time, *Ludius* (=*Corymbites*), *Lepturoides* (=*Campylus*), and *Athous*. Although the characters used do not hold for the larvae of these genera, as recognized throughout the

world, they mark the first step toward this goal. Of the species described, 17 belong to the tribe Lepturoidini. Keys are given to 7 species of *Ludius,* to 5 species of *Athous,* and to 10 species of *Elater* (tribe Elaterini). Unique features of this work are an excellent description of the general morphology of an elaterid larva and a synoptic table summarizing, for each species studied, the "form of the body," "color and sculpture," "length," "nasale," "muscular impressions of the abdominal segments," "ninth abdominal segment," and "other remarks." These characters form the basis of Henriksen's descriptions, and many other characters are quite overlooked, some of which would have assisted in the separation of closely related species. The illustrations are good for gross structure but are not at all reliable for such details as setal characters. However, these are but minor defects in an outstanding work.

Xambeu, Le Capitaine, 1912-1914: Xambeu has brought together his observations on the elaterid larvae, which he published piecemeal over a period of some 20 years. He describes the larvae of 76 species, 32 belonging to the tribe Lepturoidini and 15 to the genus *Ludius.* In making this inclusive study he has drawn freely from the writings of Beling, Perris, Schiodte, and Rey. His descriptions of the larvae of *Ludius melancholicus* (Olivier) and *Ludius amplicollis* (Germar) are original contributions, and these species apparently have not been redescribed by subsequent writers. Unfortunately, most of his descriptions are too general to provide specific distinction, and he gives no keys or figures. The chief merits of the work are the large number of species included and the addition of pertinent new observations on biology, especially on the food of the larvae.

Hyslop, J. A., 1917: The object of this study was the characterizing of the major subdivisions of the family. Supporting his conclusions by both adult and larval studies, Hyslop improved upon the pioneer work of Schiodte and Henriksen and established a reliable basis for progress in this field of research. His 3 subfamilies (exclusive of the Physodactilinae) are subdivided into 10 well-defined tribes and several other tribes that are included provisionally for forms not represented in the larval material examined. The relative ordinal value of the characters used seems to have been gauged wisely, considering the material available. The study included an examination of larval exuviae of reared specimens representing 33 genera. Characters of 5 other genera were taken from the literature. Excellent figures illuminate the brief tribal descriptions. Genera are not distinguished, and no keys are given. The paleontological record is reviewed, and the phylogeny of the family is discussed.

Roberts, A. W. R., 1919-1928: In these four papers Roberts describes representatives of *Agriotes, Athous,* and *Ludius* (=*Corymbites*). All are useful descriptions. However, his principal contribution is the excellent detailed morphological study of the larva of *Agriotes obscurus* (Linnaeus) (1921). This is a well-illustrated, careful study, the head, mouthparts, and spiracles being especially carefully done. It has been a most useful guide to ambitious modern investigators. In his 1922 paper Roberts includes a key to genera of Elateridae occurring in Great Britain. This he adapted from Henriksen and it contains little that is new.

Horst, Albert, 1922: Realizing the importance of detailed morphology, this author has undertaken to supply omissions in Beling's descriptions of the larvae of *Elater sanguineus* Linnaeus, *Ludius aeneus* (Linnaeus), and *Lacon murinus* (Linnaeus), and to describe fully *Agriotes obscurus* (Linnaeus). The work is rather carefully done, but without closely related species for comparison the author has described in much detail structures that are of no specific value and he has overlooked some of the more pertinent details. Good-sized figures illustrate the gross morphology of the species examined, but important details are lacking. There are no keys. Useful notes on biology are included in the lengthy section on this subject.

Hyslop, J. A., and Böving, A. G., 1935: This is an excellent contribution to the morphological literature. Detailed observations are recorded in an orderly fashion and through an appropriate terminology. It is a useful model for future investigators to follow. Unfortunately, several of the figures are too small to reveal the detail that they were intended to illustrate. A brief key separates the genera *Hemirhipus* and *Tetrigus.*

Lanchester, H. P., 1939: This splendid paper on the morphology of the larva of *Limonius canus* LeConte is probably the most detailed record in the elaterid literature. It is intended as a basis for future comparative studies. The text is illustrated by 16 good-sized drawings, and there is no doubt that the study has been performed with much care. In several instances the author has departed considerably in his interpretation of structure, and consequently in his terminology, from that of such workers as Böving, Snodgrass, and Anderson. It is doubtful if this departure has enhanced the value of the contribution.

METHODS AND PROCEDURE

REARING

The primary purpose of the rearing project at the Saskatoon laboratory has been to associate larval and adult stages. Considerable information on the biology of certain species has been obtained, but this has been largely incidental to the main purpose. Through the cooperation of colleagues and friends more than 4,000 elaterids have been collected for rearing. Some 250 larvae have been reared to adults and 30 others to pupae. The reared adults represent more than 50 species, of which 20 belong to the tribe Lepturoidini and 7 to the genus *Ludius*.

In the Holarctic region most species of Elateridae pupate in July or early August, and best results have been obtained from collections made just prior to or during that period. Usually a high percentage of the large larvae collected at this time pupate within a few weeks, and in addition pupae and young adults may be found in their pupal chambers along with their larval exuviae.

The largest larvae of each type were selected for rearing. Only one specimen was put in each container, which usually was a 1-ounce, 2-ounce, or 3-ounce salve tin. In this way confusion was avoided in associating adults with larval exuviae and losses from disease and predatism were minimized. The containers were nearly filled with appropriate material such as soil, wood, or leaf litter, taken from the exact spot where the larvae were found. Potato, crushed wheat, and fresh grass roots were commonly used for food and predaceous species occasionally were given decapitated coleopterous and lepidopterous larvae. Small amounts of water were added weekly to each container to keep the contents just slightly moist. Most of the rearing was done at room temperature, but some specimens were reared in controlled-temperature cabinets operating at 60° F. to 80° F. Very little benefit was noted from maintaining the larvae at any constant temperature, and varying temperatures were not thoroughly tested.

Where exact data on pupation were desired, the pupa or prepupal larva was gently transferred from its pupal chamber to a depression made on the surface of the soil (or litter), where it could be observed daily with a minimum of disturbance. Glass-topped tins or glass vials, partially filled with moist soil or litter, were used occasionally as containers for specimens under daily observation. In every instance the last larval exuvium and the pupal exuvium were preserved.

PRESERVATION AND STORAGE OF MATERIAL

When only one or two larvae of an unreared type were collected, none was preserved until after some attempt had been made to rear them, but care was taken to preserve immediately any specimens that died. When more than two larvae of the same type were collected, some were preserved at once for morphological purposes, at least one large specimen being included if there were several available.

Several different preservatives were used, but 70 percent ethyl alcohol was found to be satisfactory. Preservatives containing acetic acid distended the larvae and made them more suitable for morphological study, but the acid tended to destroy the muscles after the material had been preserved for a year or more.

Larvae and the exuviae of reared specimens were placed in small shell vials which were plugged with cotton batting and stored in pint fruit jars. Each vial contained a place-date-collector label and the record number of the specimen. The latter permitted cross reference to collecting notes and, in the case of reared specimens, insured accurate association with adults. The exuvium of a reared specimen was always kept in a separate vial and the date of emergence of its adult was recorded on the date label. Preservative was added both to the vials and fruit jars, thus giving double protection against desiccation.

Reared adults were pinned and labeled with exactly the same information as was given on the labels with their exuviae. All such adults were stored in a special collection and were not incorporated into the working collection of the laboratory.

PREPARATION OF MATERIAL FOR EXAMINATION

The general procedure followed in the preparation of the material of each species was to mount on slides the head parts of one or more specimens, then to soak the remainder of the specimen in 10-percent KOH until all muscles and viscera could be squeezed out and the specimen fully distended to reveal the sclerites of the thorax and abdomen. Such specimens were then returned to alcohol and used to supplement observations made upon entire larvae. Specimens for dissection were carefully selected to avoid badly eroded mouthparts. In many instances, parts of the thorax and abdomen were placed upon slides, and for *Ludius aeripennis destructor* the head parts of many specimens were dissected and all parts of at least one larva were mounted. Dissected parts were placed in 10-percent KOH for a few

hours, then thoroughly rinsed in water and put in 95-percent alcohol for several minutes before mounting in Canada balsam.

The study of the mandibles was facilitated, in many instances, by fastening each one with seccotine to the tip of a minuten pin, the base of which had been thrust into the small end of a cork. By inserting the cork into a vial the mandible could be stored safely. Mounts of this type were particularly useful in observing sculpture, of which only a limited view could be had from slides.

KOH was used to distend dry, hard, shriveled larvae and to soften larval exuviae so they could be made ready for examination. Ethyl acetate was also used for softening larval skins. One or two drops of ethyl acetate in a concave-bottomed dish was found helpful in manipulating small sections of exuviae under the binocular.

EXAMINATION OF MATERIAL

The material was examined by two distinct methods: first, a preliminary survey to determine the general relationships of the species that had been assembled, and second, a detailed study to obtain separating characters for closely related groups and species.

THE RECONNAISSANCE SURVEY

When the great bulk of the material had been assembled and the preparation of slides was well advanced, a comprehensive morphological survey was undertaken. This included all available species of the tribe Lepturoidini. By the method of comparative morphology a careful examination was made of the mandibles, nasale, subnasale, frons, paranasal lobes, gula, prosternum, number of spinelike setae on the episterna of the mesothorax and metathorax, setal pattern on abdominal mediotergites, "impressions" and other sculpturing of abdominal mediotergites, general type of pleural and sternal structures, and the ninth and tenth abdominal segments. Each structure was examined independently in all species before examination of the next structure was begun. Throughout this survey descriptive notes were made, numerical data tabulated, and numerous careful preliminary drawings prepared. At this time one specimen of each species was examined, rarely more. Some attempt was made to group the species on the basis of each of the above characters, and a preliminary arrangement of "species groups" was deduced from the entire evidence.

THE DETAILED STUDY

The detailed examination of *Ludius* was begun by preparing a comprehensive illustrated description of *Ludius aeripennis destructor*

Brown. Other species of the *aeripennis* group were compared with this description and differences noted and illustrated. This procedure was followed for each "species group," in each case the species described in full being that for which there was the most suitable material.

In the study of the genera related to *Ludius,* only generic and "species group" descriptions were prepared. Several specimens of each of these species were examined carefully, but particular attention was given to some 30 characters selected on the basis of the reconnaissance survey and the detailed work with *Ludius.*

Descriptions.—All descriptions were made from preserved specimens, but living material was examined when available. The largest and most perfect specimens were selected as the primary basis for each description. All these (usually from three to six specimens where available) were thoroughly examined. The remaining specimens were used extensively in determining the individual variation, especially in characters of setation and sculpture. After the morphological data were analyzed the descriptions were revised to eliminate details common to all species. Each revised description was then checked by a complete reexamination of a few larvae picked at random from the available material. All specimens were examined in checking the characters ultimately regarded as diagnostic.

The head and mouthparts were examined under the compound microscope using low and high power and occasionally oil immersion. Most of the remaining parts were described from binocular examination, using a magnification of 64 diameters in studying the sculpture and setae. Fine punctation is more readily observed on living specimens; consequently the preserved material was very carefully examined for the presence of minute pits. Such sculpturing, as well as minute setae, was best observed by firmly gripping the larva with tweezers and rotating it slowly while it was focused in strong light.

The detailed descriptions are believed to be highly accurate, but minute pores and minute setae are difficult to observe and subject to considerable individual variation, the extent of which often was not fully determined. These characters have been retained in the descriptions for the sake of completeness, but rarely are they used as a basis of identification.

Illustrations.—Each figure is drawn from a single specimen and is not a composite made up from observations on several individuals. All drawings were made by the aid of an eyepiece micrometer and cross-section paper. To facilitate comparison, a microprojector was

used to a considerable extent in the preparation of preliminary sketches of head parts, but none of these sketches were used as final illustrations.

A millimeter scale indicates the magnification of the drawings of whole larvae, but with few exceptions this is not done for the illustrations of larval parts. The writer finds himself in close agreement with Blackwelder (1936, p. 7) who states, ". . . . the magnification attained . . . . is believed to be purely incidental and of no importance to a knowledge of the morphology."

ABBREVIATIONS USED IN ILLUSTRATIONS

To clarify the terminology adopted, the list of abbreviations used in the illustrations has been expanded to include the equivalent terms that commonly appear in the literature. In addition, the less familiar terms are defined and the source of the term or of its definition is given in parentheses.

a: Anal aperture.
aed: Dorsal anteroepicranial setae (Hyslop and Boving, 1935, p. 49).
aev: Ventral anteroepicranial setae (Hyslop and Böving, 1935, p. 49).
al: Anal lobe.
ant: Antenna.
ar: Anal armature (= "scansorial hooks" auct.).
atm: Medial anterotergal seta.
br: Brace.
cd: Cardo.
cn: Caudal notch: the interspace between urogomphi (Comstock and Slingerland, 1891).
co: Condyle.
cr: Crease.
cv: Cervical sclerite (= "parietal", Lanchester, 1939, fig. 1 A, *par.*).
cx: Coxa.
dg: Dorsal groove of mandible.
distp: Dististipes: "An anterior portion of the maxillary stipes" (Boving and Craighead, 1931, p. 81).
dm: Dorsal margin of inner face of distal part of mandible.
dpla: Dorsal plate of ninth abdominal segment: the central dorsal area; in the biconvex type of elaterid larva, usually flattened, limited laterally by raised, carinate margins, anteriorly by transverse impression, posteriorly by caudal notch.
dplf: Dorsopleural fold (= "dorso-pleural groove" or "dorso-pleural line" of Snodgrass, the "ventro-lateral suture" of Böving, and the "pleural suture" of Hopkins): ". . . . a more or less distinct groove (or infolding) extending along each side of the abdomen below the line of the spiracles . . . ." (Snodgrass, 1931, p. 10, fig. 3, *a-a*).

dpr: Dorsal prongs: conspicuous prongs placed anterad to urogomphi in larvae of the subfamily Oestodinae (fig. 8, *c*).
ds: Dorsal epicranial sulcus (Hyslop and Böving, 1935, p. 50).
dsse: Dorsosulcal setae (Hyslop and Böving, 1935, p. 50).
e: Eye spot.
ephr: Epipharyngeal rod.
epla: Epicranial plate (= "parietal," Whitehead, 1932, p. 230; "gena," Lanchester, 1939, fig. 1 A, *gen*). (Roberts, 1921, p. 202.)
epm: Epimeron.
epst: Episternum.
eust: Eusternum.
ex: Expanded medial margin of mandible (fig. 35, *a*).
fcl: Frontoclypeal region (= "cephalic plate" of Roberts; "nasale and front" of Hyslop, 1917; "praefrons" of Subklew, 1934b).
fe: Femur (= "tibia," Lanchester, 1939, fig. 5 A, *t*).
fil: "Filaments" (= "setae" auct.): setalike filaments, sometimes branching, on hypopharynx, laciniae, and other surfaces in the preoral cavity (figs. 3, *g*; 4, *c*, *f*).
for: Foramen magnum (= "occipital foramen" auct.): "The opening from the head into the neck" (Snodgrass, 1935, p. 127).
fs: Frontal suture.
ga: Galea.
gu. Gula: ". . . . the area between the anteriorly extended lower ends of the postoccipital suture lying behind a line drawn between the posterior tentorial pits" (Anderson, 1936, p. 5).
hph: Hypopharynx.
hphb: Hypopharyngeal bracon: "A term introduced by A. D. Hopkins for a transverse brace between hypopharynx and the anterior part of the hypostomal margin" (Böving and Craighead, 1931, p. 82).
hphr: Hypopharyngeal rod: "Rod between hypopharyngeal sclerome and frons near antenna" (Hyslop and Böving, 1935, p. 59).
hphsc: Hypopharyngeal sclerome (= "closing plate," Lanchester, 1939, p. 14).
hs: Hypostoma: the ventral margin of each epicranial plate, between the ventral articulation of the mandible and the posterior tentorial pit.
im: Impression (= "muscular impression" of Schiodte, 1870).
ipr: Inner or lower prong of urogomphus.
lac: Lacinia.
led: Dorsal lateroepicranial setae (Hyslop and Böving, 1935, p. 49).
lev: Ventral lateroepicranial setae (Hyslop and Böving, 1935, p. 49).
lig: Ligula.
lim: Lateral impression.
loim: Longitudinal branch of impression.
lst: Laterosternite: a lateral sclerotization of the sternum distinct from a principal median sternite.
ltg I: Laterotergite I (= "paratergite" or "epipleuron"): "A lateral sclerotization of the dorsum distinct from a principal median tergite" (Snodgrass, 1935, p. 81).

ltg II: Laterotergite II.

ltga: Anterior laterotergite (= "anterior mesopleurite or metapleurite," Lanchester, 1939, fig. 5 A, *pam*): an anterolateral sclerotization of the dorsum distinct from a principal median tergite.

ltgp: Posterior laterotergite (= "posterior mesopleurite or metapleurite," Lanchester, 1939, fig. 5 A, *ppm*): a posterolateral sclerotization of the dorsum distinct from a principal median tergite.

mc: Median carina of mandible: a small longitudinal toothlike ridge on the inner surface of mandible, anterior to retinaculum and between the ventral and dorsal margins.

md: Mandible.

mg: Median groove on dorsal plate of ninth abdominal segment.

mst: Mediosternite: a median sclerotization of the sternum distinct from lateral sternites.

mtg: Mediotergite: a median sclerotization of the dorsum distinct from lateral tergites. (After Snodgrass, 1935, fig. 139 B, *mtg*.)

mtu: Median tuft of filaments between maxillulae of hypopharynx.

mxul: Maxillula (= "superlingua" or "paraglossa" auct., or "horns of the hypopharynx" of Roberts, 1921, p. 206): lateral lobes of the hypopharynx.

n. Nasale (= "clypeus" of Schiodte, 1870): an anterior and median projection of frontoclypeal region (Böving and Craighead, 1931, p. 84).

ns: Nasal sulcus (= "nasal depression," Lanchester, 1939, p. 10): a more or less linear depression on frontoclypeal area running obliquely backward from junction of nasale and paranasal lobes.

nsa: Anterior nasosulcul setae: setae arising from anterior end of nasal sulcus, in the sinuosity between nasale and paranasal lobes.

opr: Outer or upper prong of urogomphus.

ped: Dorsal posteroepicranial seta.

pen: Penicillus (= penicillum): "A small setiferous process or bunch of hairs at the base of the mandible on the inner margin" (Roberts, 1930, p. 68).

pge: Postgenal area (= "paragenal area"): the lateral parts of the posterior region of the cranium.

pim: Paramedian impression on dorsal plate of ninth abdominal segment.

pl: Pleural area or pleurite (= "hypopleuron").

plf: Maxillary palpifer.

plp: Palpus.

pmt: Postmentum (= "mentum" or "submentum" auct.; "submentum + mentum," Horst, 1922, fig. 16, "su + men"; "postlabium," Lanchester, 1939, fig. 1 B, *lpo*): "The postlabium, or basal part of the labium proximal to the stipital region, or prementum; when sclerotized, containing either a single postmental

plate, or a distal mental plate and a proximal submental plate" (Snodgrass, 1935, p. 156, adopted by Anderson, 1936, pp. 3 and 20).

pnl: Paranasal lobe (= "frontal angles" auct., "mandibular sclerite" of Henriksen, 1911, p. 227; "lateral wings of nasale," Lanchester, 1939, pp. 10-11, fig. 1 A, *nlw*): anterior projections of frontoclypeal area, on each side of nasale (Hyslop and Boving, 1935, p. 52).

pnlp: Cluster of pores on paranasal lobes (= "nasal sensory organs," Lanchester, 1939, p. 12).

por: Postoccipital ridge (Snodgrass, 1935, p. 128).

pos: Postoccipital suture (= "gular sutures") (Snodgrass, 1935, p. 128).

prmt I: First prementum (= "prementum" auct., "prelabium," Lanchester, 1939, fig. 1 B, *lpe*): anterior (visible) part of prementum in the Elateridae (Anderson, 1936, p. 20).

prmt II: Second prementum: posterior (invaginated) part of prementum in the Elateridae (Anderson, 1936, p. 20).

pro: Protuberance.

prst: Presternal area (= "acrosternite," Horst, 1922, p. 34; "brustschild," Korschelt, 1924, p. 533): the anterior area of the sternum in elaterid larvae, transverse in mesothorax and metathorax, triangular in prothorax; "prosternum" frequently used with reference to presternal area of prothorax.

pstn: Poststernellum: the most posterior part of sternum, lying behind sternellum (after Hyslop and Boving, 1935, fig. 9 A, *post*).

pt: Posterior tentorial arm.

ptp: Posterior tentorial pit (= "ventral tentorial pit" of Boving): "The external depressions in the cranial wall at the roots of the tentorial arms; . . . located . . . . in the lower ends of the postoccipital suture" (Snodgrass, 1935, pp. 128-129).

pxstp: Proxistipes: "A posterior portion of maxillary stipes" (Boving and Craighead, 1931, p. 84).

ret: Retinaculum (= "proximal lobe of mandible," Lanchester, 1939, fig. 4 C, *mpl*): "A hard, pointed, and tooth shaped process usually near or at the middle of the inner edge of the mandible; never jointed" (Schiodte's term, adopted by Böving and Craighead, 1931, p. 84).

sap: "Sensory" appendix of antenna (= "tactile papilla," "sensory process," "accessory process," or "supplementary joint").

scl: Sclerite.

sen: Sensillum: "A simple sense organ or one of the structural units of a compound sense organ" (Snodgrass, 1935, p. 549).

sn: Subnasale (= "subnasal process," Roberts, 1921, p. 205): the sclerotization on ventral aspect of base of nasale.

snf: Subnasal flap: wing-shaped membranous lining of the ventral surface of paranasal lobes and base of subnasale.

soc: Socket.

sp: Spiracle.

spla: "Sensory" plate in preoral cavity.

spsc: Spiracular sclerite: a laterotergite containing the spiracle.
st: Sternum.
stl: Sternellum: the part of sternum lying between the bases of coxae; limited anteriorly by eusternum and posteriorly by a line, real or imaginary, joining the posterior limits of attachments of coxae (after Hyslop and Böving, 1935, fig. 9 A, *stl*).
stp: Maxillary stipes (= "cardo plus stipes," Henriksen, 1911, fig. 2, "*C + St.m*," who was followed by Horst, 1922, fig. 16, "*C + stip*," and by Subklew, 1934b, fig. 2, "*CaSti*").
t: Tentorium.
tal: Talus (Hyslop and Boving, 1935, p. 52).
tg: Tergite.
ti-ta: Tibiotarsus (= "tarsus," Lanchester, 1939, fig. 5 A, *ta*): the tibia and tarsus united into one joint (after Hyslop and Boving, 1935, fig. 4, *ti-ta*).
to: Toothlike expansion on lateral aspect of ninth abdominal segment.
tr: Trochanter (= combined trochanter and femur of Lanchester, 1939, p. 33).
trim: Transverse impression or transverse branch of impression.
tub: Tubercle.
un: Ungula (= "dactylopodite" or "pretarsus" of Snodgrass). (Hyslop and Boving, 1935, p. 55.)
ur: Urogomphus (= "cercus" or "pseudocercus"): "A process, usually paired, projecting from the posterior end of tergum of the ninth abdominal segment. . . ." (Böving and Craighead, 1931, p. 85).
vm: Ventral margin of inner face of distal half of mandible.
vmth: Ventral mouthparts (= "lower jaw," Horst, 1922, pl. 1, fig. 4; "maxillo-labial apparatus," Guéniat, 1934, p. 112): the entire unit formed by the fusion of maxillae and labium (after Boving and Craighead, 1931, pl. 84, fig. N).
vr: Ventral epicranial ridge.
vs: Ventral epicranial sulcus (= "hypostomal suture," Lanchester, 1939, fig. 1 B, *hs*). (Hyslop and Boving, 1935, p. 50.)
vsse: Ventrosulcal setae (Hyslop and Boving, 1935, p. 50).
1 to 10: Abdominal segments.
I, II, III: Thoracic segments.

LISTING THE MATERIAL EXAMINED

The final criterion for the identification of larvae must be through their adults. Consequently, larvae that are not definitely associated with available reared adults are of only secondary importance in a taxonomic study. In listing such material the information given for each species has been limited to the following: The total number of larvae examined; the general localities represented, such as States, provinces, or countries; and the institutions in which the specimens

are stored. However, for larvae which, through rearing, are associated with extant adults, there have been added detailed notes on place, date, collector, record number, and other related data.

In listing the material of each species that was examined, the following abbreviations are used to indicate the institution in which the material is stored:

C.N.C.:	Canadian national collection, Ottawa, Ontario. (Material stored temporarily in the Dominion Entomological Laboratory, Saskatoon, Saskatchewan.)
B.M.:	British Museum of Natural History, London, England.
Pa.C.:	Pennsylvania Agricultural Experiment Station collection, State College, Pa. (Material temporarily stored with C. A. Thomas, Kennett Square, Pa.)
R.V.A.C.:	Royal Veterinary and Agricultural College, Copenhagen, Denmark.
U.S.N.M.:	United States National Museum, Washington, D. C.
van Emden:	Private collection of Dr. Fritz van Emden, British Museum, London.
W.W.:	United States Wireworm Laboratory, Walla Walla, Wash.

MORPHOLOGY OF A TYPICAL LEPTUROIDINE LARVA

In conducting the study a first essential was to investigate thoroughly the structure of a typical lepturoidine larva and to develop an appropriate terminology for its description. *Ludius aeripennis destructor* Brown was selected for this purpose because it was available in abundance, because of its tremendous economic importance, because it represented a large section of the genus *Ludius,* and because it was an excellent example of the tribe Lepturoidini.

TERMINOLOGY

In developing a suitable terminology, the writer has drawn freely from the works of Snodgrass (1931, 1935), Hyslop and Böving (1935), Böving and Craighead (1931), and Roberts (1921, 1930). Anderson (1936) has been followed in naming labial structures.

A survey of the literature on the morphology of the larval Elateridae reveals much confusion and uncertainty in the naming of many parts. The hypopharynx, the ventral sclerites of the thorax, and the segmentation of the leg have always been a source of difficulty.

In the present study the hypopharynx is regarded as including both the basal sclerome at the mouth of the pharynx and the adjoining membranous area extending as far forward as the transverse fold at the base of the prementum.

Hyslop and Böving (1935, p. 55, fig. 9, *a*) have been followed in naming the major divisions of the sternum in the thoracic segments. Thus the anterior ventral sclerites are regarded as *presternum;* the area lying between the presternum and an imaginary line joining the furcal pits (observable in prothorax at inner anterior margins of bases of coxae, but not evident in mesothorax and metathorax) is designated *eusternum;* the *sternellum* lies behind the eusternum, between the bases of the coxae, being limited posteriorly by an imaginary or real line joining the posterior limits of the attachments of the coxae; the *poststernellum* is the extreme posterior part of the sternum, lying behind the sternellum. This interpretation seemed best since the homology of these sclerites has never been definitely established. However, it is pertinent to note that in the mesothorax and metathorax the "presternal sclerites" take a position suggestive of "intersternites" as interpreted by Snodgrass (1935, pp. 76, 78, fig. 39 A, *Ist*).

Hyslop and Böving (1935, p. 55, fig. 4) have also been followed in naming the segments of the legs: Coxa, trochanter, femur, tibiotarsus, ungula.

MORPHOLOGY OF THE MATURE LARVA OF LUDIUS AERIPENNIS DESTRUCTOR BROWN

Length 22 mm.; greatest breadth about 2.75 mm. on fourth and fifth abdominal segments. Fully distended larvae have measured 25 mm., but pupation has been recorded (Strickland, 1935, p. 521) when specimens attained a length of only 17 mm. Body robust; dorsum more convex than venter; slightly to moderately depressed dorsoventrally, with large membranes on lateral aspect of thorax and abdomen; subparallel, with all segments broader than long, becoming narrower toward extremities; each segment widest just caudad to middle, constricted between segments. Head and ninth abdominal segment of approximately equal breadth (head slightly narrower), being about two-thirds to three-fourths greatest body width. Dorsum brownish yellow to bright yellow (near "clay color" or brighter, Ridgway, 1912), venter slightly paler; mandibles, nasale, talus, and prongs of urogomphi darker; membranes white or creamy white. Dorsum slightly rugose, sparsely punctulate. Median dorsal suture traverses all thoracic and first 8 abdominal segments, interrupted in each segment in region of longitudinally striated caudal margin.

HEAD (figs. 1, *a, b;* 2, *g*) prognathous; medium-sized; subquadrangular, with strongly arcuate sides; broader than long, widest across

middle; exclusive of appendanges, almost as thick at base as long, thinner anteriorly, maximum thickness about one-third thickness of fully distended abdomen; flattened above and below; gular area depressed.

Frontoclypeal region (*fcl*, fig. 1, *a*) well defined by distinct frontal sutures (*fs*); bearing few fine punctures. Anterior part transverse, extending laterally to bases of antennae; posterior portion longitudinal, spatulate, extending backward to or almost to foramen magnum (*for*), truncate posteriorly. Two prominent nasal sulci (*ns*) run obliquely backward from junction of nasale and paranasal lobes, decreasing in depth posteriorly, each bearing 2 prominent setae anteriorly, designated the anterior nasosulcal setae (*nsa*). Other setae present as indicated in figure 1, *a*. *Nasale* (*n*, figs. 1, *a*; 2, *c*) well developed, unidentate, terminating sharply when uneroded; strongly sclerotized. *Subnasale* (*sn*, fig. 2, *c*) consisting of strongly sclerotized transverse ridge, ventrally convex; serrate, when uneroded, with a row of approximately 8 or 9 subequal, short, sharp, forward-projecting denticles; most lateral denticles usually slightly larger, occasionally projecting beyond lateral margins of nasale. *Paranasal lobes* (*pnl*, fig. 1, *a*) strongly produced anteriorly, usually extending slightly beyond nasale; anterolateral corner extending farther forward than rest of lobe; inner margin moderately to strongly convex; outer margin straight to moderately concave; anterior ventral margin densely pilose; dorsal surface bearing 3 setae (1 very small). *Talus* (*tal*, fig. 1, *a*) dark, condyle for mandible produced and strong; short apodeme projecting ventrad from lateral aspect, curving slightly laterad.

Epicranial plates (*epla*, figs. 1, *a*, *b*; 2, *g*) large, covering lateral, posterodorsal, and posteroventral surfaces of head; infolding posteriorly to form postoccipital suture (*pos*) and internally producing postoccipital ridge (*por*, fig. 4, *a*), which expands laterally into dark irregular plates applied to inside of head capsule. Sparsely and finely punctulate. Dorsally, with 2 shallow longitudinal sulci (*ds*), each with 5 setae (*dsse*) subequally spaced, the most anterior seta being very long and sometimes farther mediad, the next less than one-half as long, the 3 most posterior setae small. Ventrally with 2 strong ridges (*vr*) and sulci (*vs*) running backward from region of ventral articulations of mandibles, posteriorly forming lateral limits of postgenae; each sulcus bearing row of 7 to 14 setae (*vsse*), usually only 2 to 5 conspicuous. Laterally, midway between dorsal and ventral sulci, with 2 pairs of long lateroepicranial setae (*led*, *lev*) arising from pits

within cuticular depressions; minute, dark "sensory" structure just ventrad to each pair; sometimes with one or more minute setae caudad to ventral pair. *Eye spot* (*e*) black, well defined, ovate or circular, just caudad to ventral margin of base of antenna; surrounded by 4 or 5 setae, including the anteroepicranial setae (*aed, aev*) so designated by Hyslop and Boving (1935, p. 50). *Hypostoma* (*hs*, fig. 4, *a*) with strongly sclerotized mesal margins to which ventral mouthparts and hypopharynx attach. *Postgenal areas* (*pge*, fig. 1, *b*) expanded mesad, but always rather widely separated; glabrous.

Gula (*gu*, fig. 1, *b*) short, wide, glabrous; defined laterally by anterior extensions of postoccipital sutures (*pos*) which terminate in indistinct posterior tentorial pits (*ptp*) at bases of cardines.

Antennae (*ant*, figs. 1, *a, b*; 2, *g*; fig. 2, *a, d*) three-segmented. First joint (*1*) clavate, one-half to two-thirds as wide as long; without setae; 3 or 4 small pores. Second joint (*2*) subcylindrical, almost as wide as long; about one-half length of basal joint; without setae; 1 or 2 pores; a few small "sensory" pegs borne distally; 1 medium-sized conical "sensory" appendix (*sap*) just ventrad to base of third joint. Terminal segment (*3*) small, about half as long as second joint and one-third as wide; 4 setae on apex.

Mandibles (*md*, figs. 1, *a, b*; 2, *g*, fig. 2, *e, f, h*) alike, of moderate length, robust; two-thirds as wide at base as long; anterior half inward bending at an angle of approximately 45°; retinaculum (*ret*) well developed. Base triangular, mesally acute; well-developed condyle (*co*) and socket (*soc*) for articulation with epicranial plate and talus, respectively. Proximal half tapering distally; ventral surface slightly granular just laterad to penicillus; smaller granular area on dorsal surface; outer aspect with profound antennal fossa and two setae; penicillus (*pen*) present, sometimes reaching base of retinaculum. Distal half pointed; outer surface convex with deep dorsal groove (*dg*); inner face slightly excavate with small median carina (*mc*), sometimes worn away, ventral margin (*vm*) of inner face sharp and slightly convex ventrally, dorsal margin (*dm*) sharp and strongly convex dorsally.

Ventral mouthparts (*vmth*, fig. 2, *g*; fig. 9, *h*), excluding appendages, almost as long as sides of head; moving as a unit forward and backward, usually in a horizontal plane, with cardines acting as hinges; whole unit from two-thirds to three-fourths as wide at bases of stipites as at anterior ends of stipites.

Maxillae (fig. 3, *c*) well developed. *Cardines* (*cd*) moderately large, subtriangular, well separated; posteriorly attenuate, ending

with small dark condyle (*co*) articulating with small dark socket on tentorium. Each cardo with Y-shaped, sometimes V-shaped, brace (*br*) running forward from condyle, outer ramus defining lateral margin of cardo, inner ramus running slightly laterad to middle, reaching and articulating with base of stipes; small seta between rami of strengthening sclerotization. *Stipes* (*stp*) large, subrectangular, sides almost straight, base truncate; usually 5 or 6 prominent setae on antero-lateroventral aspect; 1 or 2 minute setae (or pegs) and scattered pores observable under high magnification. Proxistipes and dististipes not distinct, but distal part somewhat darker, ending anteriorly in whitish membranous or semimembranous palpifer (*plf*) supported dorsally by small subtriangular sclerite (*scl*, fig. 3, *f*); anterior dorsal aspect bearing a few branched hairlike filaments.[2] *Lacinia* (*lac*, fig. 3, *c*) elongate, anteriorly bluntly pointed; borne in almost vertical plane somewhat dorsal to galea, indistinctly defined proximally; densely clothed with long, yellow, branched seta-like filaments projecting into preoral cavity. *Galea* (*ga*, fig. 3, *c*; fig. 3, *d*, *e*) two-jointed. Basal joint (*1*) subcylindrical, usually only portions sclerotized; slightly shorter than terminal joint; without setae or pores. Terminal joint (*2*) narrower than basal segment; outer margin longer than inner margin; 3 to 10 pores on latero-ventral aspect; tip (fig. *3*, *d*) inclined inward, terminating in protrusible thimble-shaped membranous process bearing many "sensory" structures. *Maxillary palpi* (*plp*, fig. 3, *c*; fig. 3, *b*) four-jointed, all joints subcylindrical. First joint (*1*) wider than long; distally on mesoventral surface with group of 4 small pores, 1 relatively large seta and 1 small seta (sometimes 1 or 2 additional minute setae). Second joint (*2*) wider than long, almost equal in size to first joint; without setae; two pores. Third joint (*3*) wider than long, about one-half length of second joint; two pores ventrally; distally with 1 small seta on mesoventral aspect and 1 near lateral aspect. Fourth joint (*4*) at least as long as wide; nearly as long as third joint; with 1 minute seta and 1 pore dorsally; group of minute "sensory" papillae on apex (fig. 3, *a*).

Labium composed of postmentum and first and second prementum. *Postmentum* (*pmt*, figs. 1, *b*; 9, *h*) elongate, sides subparallel, truncate anteriorly, bluntly rounded posteriorly. One long seta (some-

[2] These filaments are commonly referred to as "setae," but being unarticulated at the base they are not true setae in the generally accepted sense (Ferris, 1934, p. 145). Similar branched filaments are found on laciniae, prementum, hypopharynx, and elsewhere in the preoral cavity.

times also 1 smaller seta) at each corner; sometimes 1 or more tiny setae along lateral margins; a few minute pores scattered over surface. *First prementum* (*prmt I,* fig. 1, *b;* fig. 3, *i, k*) visible; pentagonal; usually with 3 prominent setae just caudad to base of each palpus, making transverse row of about 6 hairs; 2 small setae posteriorly, 1 near each lateral margin; 6 to 10 pores scattered over anterior half of ventral surface; anterior dorsal surface membranous, with 8 to 10 minute peglike "sensilla" (fig. 3, *h*); posterior dorsal aspect densely clothed with branching setalike filaments (similar to filaments on maxillae and hypopharynx). *Second prementum* (*prmt II,* fig. 3, *i*) small, transverse, firmly united to first prementum; invaginated within distal end of postmentum. *Labial palpi* (*1, 2,* fig 3, *k*) two-jointed. Basal joint (*1*) cylindrical; one-half as long as prementum; about as long as wide; sometimes with 2 or 3 small, fine setae distally on lateral aspect (observable only under high magnification and frequently absent); about 4 pores ventrally. Terminal joint (*2*) small, approximately one-half length and less than one-half width of basal segment; without setae; usually with 1 pore; group of minute papillae on apex (fig. 3, *j*). *Ligula* (*lig,* fig. 3, *i, k*) reduced to small, membranous, anterior protuberance and pair of forward-projecting setae inserted between bases of palpi.

Hypopharynx (*hph,* fig. 3, *f;* fig. 3, *g*) posteriorly limited by dark, strong, transverse hypopharyngeal sclerome (*hphsc*) with ends attached ventrally to anterior end of hypostoma by thickened membranous bracons (*hphb*) and dorsally to mesal aspect of talus by very fine membranous rods (*hphr*) difficult to observe. Maxillulae (*mxul*) membranous, lobe-shaped, projecting forward with lateral edges expanding ventrally; clothed with long, fine branching setalike filaments (*fil,* fig. 3, *g;* fig. 4, *c*). Median tuft (*mtu*) of filaments projects forward from between maxillulae. Anterior portion of hypopharynx membranous, bearing numerous branching filaments

Preoral cavity (fig. 4, *d*) large, lined with membrane attached dorsally to under surface of paranasal lobes and subnasale, laterally to mandibles, ventrally to hypopharynx and ventral mouthparts. Membrane soft and pliable except where thickened into connectives supporting hypopharyngeal sclerome. Mandibles move in V-shaped spaces between these membranous connectives to which they attach by folded membrane. Lining of dorsal surface consists mainly of transverse subnasal flap (*snf,* fig. 4, *d;* fig. 4, *f*) which together with the sclerotization of the subnasale possibly constitutes the epipharyngeal region (Hyslop and Boving, 1935, p. 52, footnote).

Subnasal flap is strengthened by two irregular "epipharyngeal rods" (*ephr*) with anterior margins drawn out into long setalike filaments (*fil*), some branching. Two small brown "sensory" plates (*spla*, fig. 4, *e, f*) lie directly caudad to sinuousities between nasale and paranasal lobes, posteriorly covered by membrane, anteriorly with 5 or 6 circular "sensilla." Remainder of dorsal lining covered by minute, pointed "sensilla" (*sen*) (base of each sensillum not articulated but continuous with membrane from which it arises), increasing anteriorly in density and in length, becoming setalike at anterior margin of subnasal flap. Ventral surface of preoral cavity well supplied with sensilla and branching filaments arising from dorsal aspect of labium and maxillae. Opening of mouth small, transverse, above base of hypopharynx; screened by sensilla and filaments of subnasal flap, hypopharynx, laciniae, prementum, and by penicilli of mandibles.

Tentorium (*t*, fig. 4, *a;* fig. 4, *b*) consisting of well-developed, unconnected posterior arms (*pt*) extending both forward and backward from region dorsad to posterior tentorial pits; posterior part of each arm produced straight backward to near base of head; anterior part ending freely in head cavity near posterolateral corner of hypopharyngeal sclerome. Short apodeme produced ventrally from lateral aspect of talus might represent vestigial anterior tentorial arm, being somewhat similar in position to structures in carabid larvae labeled by Böving (1910, p. 365, fig. 2, T) as "tentorium."

Cervical sclerites (*cv*, figs. 1, *a;* 2, *g*). Usually 2 subovate or subrectangular pale, indistinct sclerites dorsally at base of head, 1 on each side of middorsal line. Sometimes other indefinite, variable, and weakly sclerotized areas found farther caudad or laterad. One small stout seta on cervical membrane directly behind each dorsal epicranial sulcus (*ds*).

THORAX (fig. 5, *a, b*). Prothorax slightly more than three-fourths combined length of mesothorax and metathorax. All segments broader than long, each slightly wider and thicker than preceding segment.

Prothorax (*I*) wider posteriorly; slightly wider than long. *Tergites* (*tg*) not divided into medial and lateral sclerites as in mesothorax and metathorax; with anterior and posterior margins membranous and longitudinally striate; with scattered small shallow pits; without well-defined impressions; anteriorly with 7 to 10 setae (on each side of middorsal suture) arranged in transverse row, mostly in pairs; posteriorly with 5 to 8 setae in transverse row, usually ar-

ranged as 3 pairs with 1 unpaired seta farther laterad; usually without setae between anterior and posterior rows, sometimes 1 seta, rarely 2, near center of sclerite. *Episternum* (*epst*) large, anteriorly reaching sides of presternum; bearing 3 or 4 prominent setae and a few smaller hairs. *Epimeron* (*epm*) consisting of faintly striated membrane with small, narrow sclerite extending backward from point of articulation with episternum, bearing 1 to 3 small setae. *Presternal area* (*prst*) large, sclerotized, triangular, posteriorly acute; consisting of four sclerites as follows: A small posterior median sclerite, anteriorly attenuate; 2 large subtriangular lateral sclerites, striate on anterolateral aspect, with 1 stout bristle (sometimes also 1 small seta) laterad to center and a row of 5 minute setae or pegs on anteromedial aspect; and a very narrow, median, anterior piece, sometimes fused with lateral sclerites. *Eusternum* (*eust*) small, membranous or faintly sclerotized, bearing 2 tiny setae mesally; furcae (situated internally between bases of coxae) small, furcal pits shallow. *Sternellum* (*stl*) and *poststernellum* (*pstn*) indefinite, small, membranous.

Mesothorax (*II*, fig. 5, *a*, *b*) about twice as wide as long. *Mediotergites* (*mtg*) with posterior margins membranous and longitudinally striate; slightly rugose, with scattered small, shallow pits; *transverse branch of impression* (*trim*) reaching from one-eighth to one-fifth of distance from longitudinal branch to mediodorsal suture; *longitudinal branch of impression* (*loim*) very short or wanting. Anterior part of each mediotergite with 2 to 4 unpaired setae (most lateral usually longest) forming transverse row, with 1 seta within impression, 1 laterad to impression, and 1 or 2 between impression and mediodorsal suture; sometimes several minute hairs scattered across sclerite anterad to transverse branch. Posterior part of each mediotergite with transverse row of 4 conspicuous setae, arranged as 2 pairs (sometimes with 1 small seta near more lateral pair). Lateral part of mediotergite with 1 pair of large setae between anterior and posterior rows. *Posterior laterotergite* (*ltgp*) large, subovate, in posterior half of segment, bearing 1 large seta anterad to center. *Anterior laterotergite* (*ltga*) well developed, subtriangular, one-half as large as posterior laterotergite; closely applied to anterolateral margin of mediotergite; 1 small seta ventrally; *spiracle* (*sp*) bifore, larger than spiracles in abdominal segments, broadest anteriorly. *Episternum* (*epst*) subtriangular; bearing several minute setae and armed along ventral margin with up to 10 spinelike setae, usually with 6 to 8. *Epimeron* (*epm*) as on prothorax, but usually with 1 or 2 more setae posteriorly. *Presternal area* (*prst*) transverse, convex

ventrally, consisting of 3 pale sclerites as follows: A small, inconspicuous, medial piece, variable in shape but usually subrectangular, glabrous; 2 larger lateral sclerites, subovate, more strongly sclerotized than medial piece, bearing many minute setae. *Eusternum* (*eust*) membranous or very faintly sclerotized, with transverse row of 6 to 10 fine setae (usually only 6 readily observable) and sometimes with 2 minute paramedian setae farther forward. Furcal pits absent. *Sternellum* (*stl*) membranous, glabrous. *Poststernellum* (*pstn*) membranous except for 2 inconspicuous, tiny, subtriangular posterior sclerites; glabrous.

Metathorax (*III*, fig. 5, *a, b*) very similar to mesothorax. *Anterior laterotergite* (*ltga*) without spiracle.

Legs (fig. 5, *b, d*) well developed, subequal in length, strong. *Coxa* (*cx*) sessile, oval, excavated on outer surface for reception of trochanter and femur; usually from 30 to 40 spinelike setae on anterior aspect, arranged in irregular longitudinal rows; several setae, some spinelike, scattered over posterior surface. *Trochanter* (*tr*) subcylindrical, outer face short, inner face about one-half length of coxa, with 10 to 15 spinelike setae and a group of 5 or 6 pores on medioanterior surface; 8 to 12 such setae and 1 fine seta scattered on medioposterior surface; 2 well-developed fine setae on medial aspect. *Femur* (*fe*) obliquely attached to trochanter; subcylindrical, outer face longest; about as long as trochanter, but slightly narrower; usually with 8 to 11 spinelike setae on medioanterior surface; 3 to 5 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. *Tibiotarsus* (*ti-ta*) subcylindrical, about as long as femur but narrower; 5 or 6 setae (some rather short and stout) around distal margin; 4 to 6 spinelike setae and 1 slender seta on medioanterior surface; 3 spinelike setae on posterior surface. *Ungula* (*un*) well developed, when uneroded almost as long as tibiotarsus; dark, curved; base expanded mediad; small medial sclerite at base, bearing 2 fine setae.

First to Eighth Abdominal Segments (figs. 2, *b*; 6, *a, b, c*) subequal; when fully distended, each segment is almost as thick as wide; first segment shortest; fourth to sixth segments widest. *Mediotergites* (*mtg*) with scattered small, shallow punctures; posterior margins longitudinally striate. Prominent right-angled *impression* (*im*) on anterolateral aspect of each mediotergite, inner margin slightly sunken and pale, outer margin darker and somewhat sinuate; *transverse branch* (*trim*) curving slightly backward, on second to eighth segments extending approximately one-third distance from

longitudinal branch to middorsal suture, slightly shorter on first segment; *longitudinal branch* (*loim*) running parallel to lateral margin of sclerite, extending from one-half to three-fourths distance from transverse branch to posterior transverse row of setae. Anteriorly on each mediotergite 1 fine seta near medial end of impression and 1 small seta between end of impression and middorsal suture; sometimes a few minute setae scattered anterad to and mesad to impression. Posteriorly on each mediotergite, 3 pairs of long setae (only 2 pairs on first segment) forming transverse row, sometimes also 1 or 2 unpaired minute setae. Laterally, with 1 very small seta (frequently wanting) near posterior end of impression, and 2 (rarely 3 or 4) unpaired setae laterad to impression. *Laterotergite I* (*ltg I*) large, elongate, extending length of segment; heavily sclerotized; bearing 4 or 5 setae, 3 or 4 near dorsal margin and 1 near point of articulation with laterotergite II. *Laterotergite II* (*ltg II*) small; indistinctly defined and variable; articulating with anteroventral aspect of laterotergite I and extending forward to near anterior border of segment; glabrous. *Spiracular sclerite* (*spsc*) small, subovate, situated in anterior half of segment between mediotergite and laterotergite I; surface somewhat elevated just anterad to spiracle. *Spiracles* (*sp*) bifore, subequal in size; widest anteriorly; situated in posterior half of spiracular sclerite. Tergal and pleural areas separated by dorsopleural fold (*dplf*). *Pleurite* (*pl*) large, subovate, somewhat attenuate posteriorly; in posterior half of segment; strongly sclerotized; bearing 4 setae, one much longer than others; becoming gradually smaller from first to eighth segment. *Sternum* (*st*) usually of 1 piece, large, subquadrate, with faint longitudinal striations on posterior margin; with 2 faint anterior impressions (*im*) meeting mesally, and 2 prominent lateral impressions sometimes (especially on first abdominal segment) separating off laterosternites (*lst*); 8 to 14 setae, mostly around margins.

Ninth Abdominal Segment (figs. 6, *d*; 7, *a*, *d*), exclusive of urogomphi, about as long as eighth abdominal segment and four-fifths as wide; three-fourths as long as wide; sides of anterior half subparallel, posterior half tapering caudally, making width at anterior margin of caudal notch from two-thirds to three-fourths greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. *Dorsal plate* (*dpla*) irregularly lined and wrinkled; with small punctures (like pin pricks) sometimes increasing in size and density anteriorly; 4 shallow longitudinal impressions, 2 laterally (*lim*) and a paramedian pair (*pim*)

which converge posteriorly and usually meet in a short median groove (*mg*); without setae except at lateral margins, which are slightly raised and carinate, bearing 3 prominent blunt "teeth" (*to*), each with a long bristle; *transverse impression* (*trim*) usually rather weak, indefinite, and interrupted in middle, rarely continuing completely across segment as a somewhat wavy line bulging anteriorly at middle. Tergite (*tg*) continues uninterruptedly laterally and on posterior ventral surface; usually with from 18 to 25 unpaired setae (some small) on each side, some issuing from small, sclerotized tubercles; anteriorly on lateral aspect with a few small punctures, some with minute hairs. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth to one-fifth of total length of segment (exclusive of urogomphi). *Pleural area* (*pl*) large, consisting of transversely striated membrane except at anterior end, where there is small ovate pleurite bearing several extremely minute setae. *Sternum* (*st*) of 2 sclerites, separated anteriorly by median suture and posteriorly by tenth abdominal segment; each sclerite with from 9 to 14 setae, mostly in row around tenth abdominal segment; posterior margin membranous and striate, articulating with tenth segment.

Urogomphi (*ur*, figs. 6, *d*; 7, *a*, *d*; fig. 7, *b*, *c*) separate, bifid, short and stout; prongs short, robust, subequal. *Inner prong* (*ipr*) directed caudad in horizontal plane, turning slightly mesad, with short, sharp point turning upward and usually inward; prominent tubercle (*tub*) on ventro-caudolateral surface from inner margin of which a large bristle extends backward, another prominent seta issuing from just above inner margin of tubercle or from upper part of tubercle; 1 long seta ventrally at base of prong or slightly farther anterad; sometimes 1 or 2 minute setae around distal part of prong. *Outer prong* (*opr*) projected dorsad or caudodorsad with sharp, horny point inclined backward; 1 prominent seta on anterolateral aspect about halfway up prong; up to 10 short fine hairs around distal part of prong; 2 large setae ventrally at base or near base of prong, arising from upper margin of small tubercle. Undivided part of urogomphus with 1 stout seta ventrally near base. An occasional specimen has more setae on prongs than described above.

Caudal notch (*cn*) large, U-shaped, usually wider than long, somewhat narrowed posteriorly by incurving tips of inner prongs.

TENTH ABDOMINAL SEGMENT (*10*, figs. 6, *d*; 7, *d*) short, tubular, directed caudoventrad; terminal portion membranous, striate; with 2 whorls of about 10 fine setae, the more proximal whorl varying

from 8 to 14 hairs; without "armature" (= "scansorial hooks" auct.); anal aperture (*a*) linear and median.

KEYS AND DESCRIPTIONS

In using the keys and descriptions it is suggested that the following points be kept in mind: (1) The common structural differences between young and mature larvae of the same species; (2) the general dependability of the various taxonomic characters; and (3) criteria by which to appraise the adequacy of larval descriptions.

The characters presented in this study were taken from mature or nearly mature larvae wherever such were available. With less mature specimens certain structures will be found in relatively smaller numbers, e.g., setae, tubercles, denticles, and pits; and these and other structures in relatively smaller size, e.g., grooves, impressions, and small sclerites such as in a divided prosternum; whereas in very immature larvae some structures, especially the nasale, caudal notch, and urogomphi, may be of a quite different character. The number of larval instars through which individuals pass is known to vary so widely within a single species (Strickland, 1939) that no attempt has been made to determine or to suggest the relative maturity of the specimens examined. However, the key characters used are believed to hold for larvae of a considerable range of maturity, at least for all specimens that are more than half grown.

Every structure has potential taxonomic value. However, certain structures repeatedly have proved to be important, whereas others rarely have mattered. Differences in size and shape of definite sclerites such as the frontoclypeal area, prosternum, and pleurites are useful and entirely reliable features, whereas "sensory" structures such as pores, minute setae, and various sensilla are highly variable and only rarely are of taxonomic importance. Characters that are commonly used are briefly discussed below.

Size is a useful supplementary character, especially if a very large specimen is encountered. However, it must be used with considerable care because a shrunken larva might measure as much as one-fourth longer when fully distended, and many half-grown larvae would be within the size range of several species.

Body form has taxonomic value, but in the Lepturoidini many species have large lateral membranes that may be infolded or distended, thus changing the general shape of the specimen and impairing the practical value of the character. However, some species are normally flattened, others typically cylindrical; some are relatively

broad, others narrow; some are widest in the midabdominal region, others across the thorax. Within these limits the character is rather dependable.

Color differences usually are not reliable except between marked contrasts such as pale yellow or dark brown, not patterned or distinctly patterned, and larva unicolorous or dorsum much darker than venter. Allowance must be made for the lack of uniform expression and interpretation in the use of color and for the fact that mature larvae may be darker than younger individuals, recently moulted specimens are paler, and preserved material frequently becomes darker.

The ninth abdominal segment offers the most important diagnostic characters and should always be examined carefully, giving special attention to the caudal notch, the urogomphi, and the dorsal plate. Erosion may dull the points of the urogomphi, tubercles, and "teeth," but important specific and generic characters are more frequently drawn from this segment than from any other part of the larva.

Prominent sculpturing such as deep pits, transverse rugae, and tergal impressions appear to be reliable characters. Small or callow specimens have less conspicuous sculpturing than large or fully darkened specimens of the same species. The density of punctures and the length of impressions vary considerably and usually require observation on a good series of specimens to establish the common range of variation.

Setae often vary markedly both in number and in arrangement. However, they are usually reliable for distinguishing such contrasts as "setae absent or present" and "setae paired or unpaired." In specimens in good condition the setal arrangement on the abdominal mediotergites is generally dependable, but occasionally an individual is found with almost double the normal complement of hairs. Young larvae have fewer setae than older specimens. For these reasons, setal characters should be supported by other evidence where possible. The number of spinelike setae on the various segments of the legs and on the thoracic episterna should not be relied upon unless the differences are marked and constant.

The nasale is a very useful structure. It is subject to considerable erosion, but in the great majority of larvae the general type of nasale can be determined even when worn. Where there are small lateral denticles which soon wear away the structure loses much of its taxonomic value. However, workers should become familiar with all common types of nasale so that they can be recognized even when eroded.

The subnasale is a useful supplementary feature, but it is seriously eroded too frequently to be generally reliable.

Mandibles of distinct types provide splendid separating characters. Erosion dulls and shortens the points, but only minute carinae and denticles are likely to be completely worn away.

Antennae are of limited value. Sometimes the shape of the segments or their relative length is characteristic, but more often it is the number of "sensory" appendices on the second segment. This character is decidedly valuable, but as with many other sensory structures a knowledge of normal variation is essential to its proper use.

Eyes present or eyes absent is an excellent supplementary character, but the pigmented ommatidia may be displaced, especially in prepupal and premoult specimens. However, in species that have eyes the epicranial plate is not pigmented in the region normally occupied by the eye, and the presence of a clear spot at the appropriate location may be taken as evidence of the presence of eyes.

Spiracles are difficult to examine or to use except in their grosser aspects. Marked differences in size, shape, or position in the segment offer good characters, but the writer has found it impractical to attempt distinction on the basis of the number of transverse trabeculae. In fact, the basic structure of the bifore spiracle seems to be a controversial matter requiring further careful research.

The power to appraise descriptions and to use them is materially increased if one fully appreciates the main factors concerned in the making of adequate larval descriptions, namely, suitable material, detailed examination, and comparison with closely related species.

Suitable material must include larval exuviae of available reared adults, as proof of identification, but whole larvae are necessary for proper morphological examination. Several specimens of each species should be available so that individual variation can be appraised. The structures that vary and the degree of variation differ from species to species and cannot be predicted.

Detailed examination is essential. Experience has shown that larvae of closely related species are morphologically very similar. Specific characters frequently are inconspicuous and are entirely overlooked or inadequately described in a superficial study.

Wherever possible the study should be comparative and the comparison must include the closest allies known. This point is illustrated by the *Ludius* larvae occurring in Saskatchewan, where nine species are recognized in the larval stage. These belong to eight different

"species groups." Were these nine species described solely with reference to one another, a separation would be effected on the basis of group characters, not on specific characters, and the descriptions would likely be inadequate for separating these species from their close allies. Larvae of the same "species group" usually differ mainly in a certain set of characters which cannot be determined in advance. For example, in the *Ludius fallax* group specific identification depends primarily upon the relative length of the urogomphal prongs, the number of "sensory" appendices on the second segment of the antenna, and the shape of the posterior part of the frons, whereas in the *aeripennis* group such characters have no specific value and identification is made largely through the number of setae on the central dorsal area of the ninth abdominal segment. In describing a larva that has no known close allies there is no guide as to the structures that hold the greatest specific value and, therefore, there is less chance of preparing a description of lasting worth.

LARVAL CHARACTERISTICS OF THE FAMILY ELATERIDAE

The elaterid larvae are diverse in form, as shown in figure 8, but family recognition is possible, in almost every instance, by the following combination of characters: Thoracic legs present, well developed, subequal, five-segmented (counting the terminal claw as a segment); labrum absent or fused with clypeus and anterior margin of frons into a rigid nasale (*n*, figs. 1, *a*; 9, *a*, *j*); frontoclypeal area usually lyre-shaped (*fcl*, fig. 1, *a*; fig. 9, *a*, *j*); maxillae and labium elongate, and fused into a single unit (figs. 1, *b*; 9, *c*, *h*) with bases inserted far behind the articulation of mandibles; body straight with 9 abdominal segments visible dorsally, the ninth with or without paired terminal processes (urogomphi); the tenth abdominal segment bears the anus and lies ventrad (usually ventrocephalad) to the ninth and may or may not be armed with sclerotized structures; spiracles bifore. In the Cardiophorinae (fig. 8, *a*) each of the second to seventh abdominal segments is divided transversely into 3 pseudosegments.

A more extensive general description of an elaterid larva is given by Henriksen (1911, pp. 226-231; translated into English on pp. 278-283), and the family is separated in the larval keys of Roberts (1930) and of Böving and Craighead (1931). A working knowledge of the general morphology of elaterid larvae is given by Glen, King, and Arnason (1943).

KEY TO SUBFAMILIES OF THE ELATERIDAE AND TO TRIBES OF THE SUBFAMILY PYROPHORINAE

1. Ninth abdominal segment with a median caudal notch (*cn*, fig. 8 *c*, *d*), sometimes small[8] 2
   Ninth abdominal segment without a median emargination (fig. 8, *a*, *b*).. 3
2. Ninth abdominal segment bearing 2 large dorsal prongs anterad to the urogomphi (*dpr*, fig. 8, *c*); nasale minute or wanting; mandibles with retinaculum; tenth abdominal segment without "armature" ....Subfamily **OESTODINAE**
   Ninth abdominal segment without prongs anterad to urogomphi (figs. 8, *d*; 9, *i*; 10, *f*; 11, *g*); nasale well developed (*n*, fig. 9, *a*, *j*) ....Subfamily **PYROPHORINAE** 4
3. Abdomen with pseudosegmentation (fig. 8, *a*); mandibles deeply cleft into dorsal and ventral branches; spiracles placed upon retractile papillae; tenth abdominal segment bearing accessory anal lobes (*al*) ....Subfamily **CARDIOPHORINAE**
   Abdomen without pseudosegmentation (fig. 8, *b*); mandibles with retinaculum; nasale well developed.................Subfamily **ELATERINAE**
4. Postmentum triangular (*pmt*, fig. 9, *c*)............................. 5
   Postmentum subrectangular (*pmt*, fig. 9, *h*)..Tribe **LEPTUROIDINI** (p. 33)
5. Mandibles without teeth on inner aspect (fig. 9, *d*, *e*); tenth abdominal segment usually with "anal armature" (*ar*, fig. 9, *i*) ....Tribe **PYROPHORINI**
   Mandibles with 3 teeth on inner aspect..................Tribe **PITYOBINI**

LARVAL CHARACTERISTICS OF THE TRIBE LEPTUROIDINI

On the basis of larval characters, the tribe Lepturoidini includes the species separated by Leng (1920) into the tribes Lepturoidini, Hypnoidini, and Melanactini.

Hyslop (1917) characterized the tribe as follows: Postmentum broad caudad, mandibles with teeth on inner surface, and tenth abdominal segment without armature. There is no doubt that these are the primary diagnostic characters of this group. However, a more nearly complete characterization of a lepturoidine larva would be: Ninth abdominal segment emarginate posteriorly (*cn*, figs. 8, *d*; 10, *a*, *f*; 11, *a*) and without dorsal prongs anterad to urogomphi; tenth abdominal segment without armature; the bases of stipites distinctly separated and postmentum subrectangular (*pmt*, fig. 9, *h*); mandibles with 1 or more teeth on inner surface (figs. 2, *e*; 9, *f*, *g*); nasale well developed (*n*, figs. 9, *j*; 19, *b*); gula present (*gu*, figs. 1, *b*; 19, *f*; 27, *b*), sometimes very narrow; and cardines moderately large (*cd*, figs. 9, *h*; 22, *b*).

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[8] In larvae of the genus *Hemirhipus* (q.v. Böving and Craighead, 1931, pl. 84 G) the urogomphi are fused except at the tips, resulting in a small but distinct notch. In some first-instar larvae this notch may be closed (op. cit. pl. 85 O), but the line of fusion of the urogomphi is evident.

KEY TO GENERA, ISOLATED "SPECIES GROUPS," AND ISOLATED SPECIES OF THE TRIBE LEPTUROIDINI

1. Urogomphi undivided (*ur*, fig. 10, *a, b*) 2
   Urogomphi divided: prongs subequal (figs. 10, *f*; 11, *f*; 12, *a, f*), or unequal (figs. 11, *a*; 12, *b, c, e*) 3
2. Urogomphi blunt (fig. 10, *a*); abdominal pleurites absent (fig. 10, *c*) ....**Eanus** (p. 187)
   Urogomphi sharp (fig. 10, *b*); abdominal pleurites large **Hypnoidus** (p. 186)
3. Head bearing dorsal posteroepicranial setae (*ped*, fig. 10, *g*); thoracic segments and first 8 abdominal segments bearing medial anterotergal setae (*atm*, fig. 10, *g*) 4
   Without dorsal posteroepicranial setae; usually without medial anterotergal setae 7
4. Ninth abdominal segment (fig. 10, *f*) with sharp "teeth" (*to*) on sides of dorsum and 2 setae on central dorsal area; Australia ....**Crepidomenus queenslandicus** Blair (p. 181)
   Ninth abdominal segment with well-rounded "teeth" on sides of dorsum and 4 setae on central dorsal area 5
5. Abdominal mediotergites (as in fig. 12, *d*) with conspicuous transverse rugae (crescent-shaped shallow pits, which are sometimes confluent); eyes absent; larvae attaining more than 30 mm. in length ....**Melanactes densus** LeConte (p. 189)
   Abdominal mediotergites without such sculpturing; eyes present....... 6
6. Abdominal mediotergites with transverse branch of impressions extending to or practically to the mediodorsal suture on second to eighth segments ....**Ludius, the nitidulus group** (p. 111)
   Abdominal mediotergites with transverse branch of impressions extending approximately one-half the distance from the longitudinal branch to the mediodorsal suture..........**Cryptohypnus** (p. 183)
7. Spiracles in eighth abdominal segment (*sp*, fig. 11, *e*) twice as long as spiracles in seventh abdominal segment.......... ....**Ludius**, the **pyrrhos group** (p. 147)
   Spiracles subequal in size in seventh and eighth abdominal segments.... 8
8. Presternum of prothorax divided into 2 or more sclerites (*prst*, fig. 10, *d*) ....**Ludius**, pars majora (p. 35)
   Presternum of prothorax undivided, of 1 large triangular sclerite (*prst*, fig. 10, *e*).......... 9
9. Caudal notch small (figs. 11, *a, f*; 12, *b*) 10
   Caudal notch large (fig. 12, *a, e, f*) 16
10. Outer prongs of urogomphi reduced to mere tubercles (*opr*, fig. 11, *a, d*) ....**Limonius**, pars (p. 157)
    Outer prongs of urogomphi definitely pronglike (*opr*, figs. 11, *b, g*; 12, *b*) 11
11. Outer prongs of urogomphi not longer than inner prongs (fig. 11, *f-h*). 12
    Outer prongs of urogomphi much longer than inner prongs (fig. 12, *b*) 15
12. Ninth abdominal segment with a distinct (sometimes short) mediodorsal groove (*mg*, fig. 11, *f*); eyes present; North America.......... 13
    Ninth abdominal segment without a mediodorsal groove (fig. 11, *g, h*); eyes absent in North American species.......... 14

13. Outer prongs of urogomphi (*opr*, fig. 11, *b, f*) projected caudodorsad and usually slightly laterad, not curving anteriorly, tip blunt; abdominal mediotergites usually with impressions extending to the mediodorsal suture in second to fifth segments.................... ....**Ludius resplendens aerarius** (Randall) (p. 136)
    Outer prongs of urogomphi (*opr*, fig. 11, c) projected dorsad, curving anteriorly, tip sharp; abdominal mediotergites with impressions definitely not reaching to mediodorsal suture..................... ....**Elathous bicolor** (LeConte) (p. 167)
14. Ninth abdominal segment (fig. 11, *g*) with well-rounded "teeth" (*to*) on sides of dorsum........................**Limonius**, pars (p. 157)
    Ninth abdominal segment (fig. 11, *h*) with prominent pointed "teeth" (*to*) on sides of dorsum....**Ludius**, the **limoniiformis** group (p. 150)
15. Dorsum very dark, usually dark reddish brown to brownish black; abdominal mediotergites punctulate, but without transverse rugae; inner prongs of urogomphi (*ipr*, fig. 12, *b*) smooth, without posterior tubercles ....**Lepturoides** (p. 168)
    Dorsum never dark, usually yellow to yellowish brown.**Athous**, pars (p. 170)
16. Ninth abdominal segment (fig. 12, *e*) without a mediodorsal groove, with four setae on central dorsal area, and with very long outer urogomphal prongs (*opr*); without impressions on mediotergites of mesothorax and metathorax..**Ludius divaricatus** (LeConte) (p. 118)
    Ninth abdominal segment (fig. 12, *f*) with a mediodorsal groove (*mg*), and without setae on central dorsal area; with definite impressions on mediotergites of mesothorax and metathorax................. 17
17. Eyes absent; abdominal mediotergites (fig. 12, *d*) with prominent transverse rugae (crescent-shaped, shallow pits which are sometimes confluent); urogomphal prongs (fig. 12, *f*) subequal, outer prongs pointed when uneroded.. ....**Hemicrepidius**, and **Athous niger** and its allies (p. 178)
    Eyes present; American species with prominent pits or rugae, European species sparsely punctulate; outer urogomphal prongs either with bluntly rounded tips (*opr*, fig. 12, *a*) or much longer than inner prongs (fig. 12, *c*)..........................**Athous**, pars (p. 170)

Genus LUDIUS Eschscholtz[4]

FIGURES 1-7; 8, *d*; 9, *h, j*; 10, *d*; 11, *b, e, f, h*; 12, *e*; 13-29

For many years nomenclatorial confusion has involved the insects now recognized under the generic name of *Ludius* Eschscholtz. Referring to this situation, Hyslop (1921, p. 621) states, ". . . the genus *Elater*, as recognized by contemporary coleopterists, is in reality the genus *Ampedus*, the insects now recognized under the

[4] Recent publications by Dietrich (1945, p. 19) and Lane (1948, p. 182) suggest that *Ludius* Eschscholtz should be placed in synonomy under *Ctenicera* Latreille. (Vide: Henry Dietrich, "The Elateridae of New York State," Mem. 269, Cornell Univ. Agr. Exper. Stat., Ithaca, N. Y., Jan. 1945; M. C. Lane, "Some Generic Corrections in the Elateridae I," Proc. Ent. Soc. Washington, vol. 50, No. 7, pp. 179-182, Oct. 1948.)

generic name *Ludius* being truly *Elater*. *Ludius*, on the other hand, should be applied to the insects generally known as *Corymbites*, and *Corymbites* as a generic name disappears." North American writers, in general, follow Hyslop and use *Ludius* instead of *Corymbites*, but European coleopterists still cling to the latter or to one or another of the subgenera recognized by Schenkling (1927). In the present study the name *Ludius* Eschscholtz includes all species of the following generic and subgeneric names: *Actenicerus* Kiesenwetter, *Anostirus* Thomson, *Aphotistus* Kirby, *Calambus* Thomson, *Corymbites* Latreille, *Ctenicera* Latreille, *Ctenicerus* Stephens, *Diacanthus* Latreille, *Haplotarsus* Stephens, *Hypoganus* Kiesenwetter, *Liotrichus* Kiesenwetter, *Prosternon* Latreille, *Selatosomus* Stephens, and *Tactocomus* Kiesenwetter.

Where possible, the names proposed by Brown (1935, 1936) for various "species groups" of *Ludius* have been used.

Knowledge of the larvae of the genus *Ludius* is based upon 44 species, 29 occurring in North America and 16 in Eurasia, one being common to both regions. All these, except 6 Eurasian species, have been examined in the present study.

The genus is extremely diverse, both in habit and in structure. Larvae occur normally in soil, decaying wood, and forest litter, but specimens have been found also in cow dung, mushrooms, and sphagnum, and under stones. Some species prefer dry situations, others require abundant moisture. In the world as a whole, *Ludius* is the most destructive genus in the Elateridae. But even the most phytophagous species seem capable of sustaining themselves for periods of months or years on decomposing organic matter, or of reverting to predaceous habits when opportunity or necessity arises. Some species are chiefly entomophagous and have never been associated with damage to cultivated plants. Larvae have been known to attack spiders, the active and inactive stages of various insects, and even members of their own species.

With the exception of a few pest species, the life history is either unknown or very incompletely known. On the basis of the information available, the common normal life cycle is as follows: The adults mate and lay their eggs in May and June; the eggs hatch within a few weeks; the larvae live for 3 or more years, pupating, when mature, in July or August; the adults develop within a month after pupation and remain in their pupal chambers until the following spring. Pupation occurs in June with some species, and undoubtedly other exceptions will be found as our knowledge of the biology of

the group increases. Only one record has been found in the literature to date of any species of *Ludius* (*L. amplicollis*) normally completing its life cycle within 1 year.

Concerning the structural features of the genus *Ludius*, Henriksen (1911, p. 258) states (translation): "A genus which it is very difficult to define, as the known larvae show such variation in characters." The writer agrees fully with this statement. So much heterogeneity exists in the larvae assembled that no single character or combination of characters has been found which adequately defines the assemblage as a natural group.

However, all *Ludius* larvae examined have the urogomphi bifid and are thus distinguished from *Hypnoidus* and *Eanus*. Separation from *Cryptohypnus* and *Crepidomenus* is obtained for all known *Ludius*, except the *nitidulus* group, through the absence of dorsal posteroepicranial setae (*ped*, fig. 10, *g*). With the exception of seven species (*divaricatus, resplendens, sjaelandicus, pyrrhos, protractus, limoniiformis*, and *cylindriformis*), all the *Ludius* examined have the prosternum divided and are thus separable from the larvae of *Limonius, Elathous, Lepturoides, Athous, Hemicrepidius*, and *Melanactes*. Of these seven species, *divaricatus* is quite isolated from other known Lepturoidini, and the other six probably are annectant species, as mentioned by Van Dyke (1932, p. 389), connecting *Ludius* with *Limonius* and with the *Athous* complex.

Because of these findings the writer feels justified in stressing the taxonomic value of characters of the prosternum. By combining the characters of the caudal notch and the prosternum, four major groups of *Ludius* have been established. These form a good working basis for the identification of the larvae of this genus.

Group I: Caudal notch small (fig. 14, *b, g*); prosternum divided into two or more sclerites (figs. 10, *d;* 13, *a*). This combination of characters is unique in the known Lepturoidini with the exception of *Eanus*, which is readily distinguished by the undivided urogomphi. This group includes the *cupreus* group, *appressus* (Randall), and *sjaelandicus* (Müller).

Group II: Caudal notch large (figs. 13, *h;* 14, *c, i, j*); prosternum divided into two or more sclerites (figs. 10, *d;* 13, *a*). *Cryptohypnus* and *Crepidomenus* larvae also possess these characters, but are distinguished by a combination of sculptural and setal patterns. This group includes two-thirds of the species of *Ludius* known in the larval stage: *aeripennis* group, *inflatus* group, *edwardsi* group, *semivittatus* (Say), *propola* group, *triundulatus* group, *fallax* group, *rotundicollis* group, *bipustulatus* (Linnaeus), and *nitidulus* group.

Group III: Caudal notch small (fig. 11, *f, h*); prosternum undivided, consisting of one triangular sclerite (fig. 13, *b*) sometimes deeply incised on posterolateral aspects. This combination of characters is found in all species of *Limonius, Elathous*, and *Lepturoides*, and in many species of *Athous*. Proper characterization of the *Ludius* that fall in this group can be made only on the basis of "species group" characters as given in the key to genera, isolated species groups, and isolated species of the tribe Lepturoidini (p. 34) or as discussed under the species groups concerned: *pyrrhos* group, *limoniiformis* group, and *resplendens aerarius* (Randall).

Group IV: Caudal notch large (fig. 12, *e*); prosternum undivided, consisting of one large triangular sclerite, much as represented in figures 10, *e* and 13, *b*. These characters are found in *Hypnoidus, Hemicrepidius, Melanactes*, and in some *Athous*. The only *Ludius* falling in this group is *divaricatus* (LeConte) and it is readily separated from other known Lepturoidini by the characteristic ninth abdominal segment (fig. 24, *c, d*).

Considering the genus in the broad sense in which it is currently recognized, the mature larvae may be described as follows, characters common to all species being marked with an asterisk:

Length 14 to 30 mm. Shape varying from the robust *pectinicornis*, measuring 28 mm. by 4 mm., to the relatively slender *cylindriformis*, measuring 30 mm. by 2.6 mm. Body usually widest across fourth abdominal segment, but in some species widest across thorax and first 2 abdominal segments; some species very robust with relatively small pleural membranes, others flattened with conspicuous large pleural areas. Dorsum pale yellow to very dark brown; without color pattern or distinctly patterned. *Urogomphi always bifid. Urogomphal prongs varying tremendously as to shape and relative length. Caudal notch large or small; posterior aperture varying from wide to almost closed. *Dorsum of ninth abdominal segment always with "teeth" on lateral margins. Dorsal plate of ninth abdominal segment varying from very convex to almost flat, the following characters being present or absent: setae on central area, large pits, median groove, and transverse impression. Frontoclypeal region reaching to foramen magnum or failing to attain foramen; terminating truncate, broadly rounded, or bluntly pointed. Nasale of one tooth terminating in one or three points. Subnasale highly variable. Eyes present (usually) or absent; from 2 to 6 setae around each eye or eye region. From 2 to 7 lateroepicranial setae in unpaired or paired arrangement. Each dorsal head sulcus with 4 or 5 setae, sometimes additional minute setae. Gula short and wide, or short and narrow, or elongate and

narrow. *Antennae with basal segment longest and terminal segment shortest. One to 6 "sensory" appendices on second segment of antenna. *Mandibles with well-developed retinaculum and without other prominent teeth. Proxistipes and dististipes not distinct except in *rotundicollis* group. From 2 to 8 prominent setae on antero-latero-ventral aspect of stipes. *Second segment of maxillary palpi without setae. Postmentum with 1 or 2 setae at each corner. *Second segment of labial palpi not longer than first segment. Presternum of prothorax of 1, 2, 3, or 4 sclerites. Each episternum of mesothorax and metathorax without spinelike setae or bearing from 1 to 10 such setae. Legs bearing many spinelike setae, number and arrangement variable. *Abdominal mediotergites (segments 1 to 8 inclusive) usually punctulate without prominent transverse rugae or large deep pits. Abdominal mediotergites bearing "impressions," length variable; setal pattern highly variable in both number and arrangement. Abdominal pleurites vary from "almost wanting" to well developed. Sternum in first to eighth abdominal segments either of 1 or 3 sclerites. Abdominal spiracles usually subequal and in anterior half of each segment; sometimes in posterior part of eighth segment; sometimes enlarged in eighth segment. Tenth abdominal segment with anal aperture linear or T-shaped.

KEY TO "SPECIES GROUPS" AND ISOLATED SPECIES OF LUDIUS [5]

1. Caudal notch large (figs. 13, *h, i;* 14, *c, i*)........................... 2
   Caudal notch small (figs. 11, *f, h;* 14, *b, g*)........................... 12
2. Presternum of prothorax divided into 2 or more sclerites (*prst,* figs. 10, *d;* 13, *a*); eyes present (indistinct in *edwardsi* and *semivittatus* groups) 3
   Presternum of prothorax undivided, of 1 large triangular sclerite (*prst,* fig. 13, *b*); eyes absent; ninth abdominal segment (fig. 12, *e*) as figured.........................**divaricatus** (LeConte) (p. 118)
3.[6] Urogomphi with tips of outer prongs sharp and inclined backward (*opr,* fig. 13, *d, e, f, i*); spinelike setae present on episterna of mesothorax and metathorax; abdominal mediotergites with prominent posterior setae arranged in pairs (fig. 14, *e, f*) (species primarily phytophagous) 4

[5] This key does not include the European species *Ludius melancholicus* (Fabricius), *L. amplicollis* (Germar), and *L. affinis* (Paykull). Larvae of these species were not available for examination and key characters and relationships are not known. For descriptions of these species see pp. 64, 64, 93, respectively.

[6] In this couplet, any one of the three characters listed will provide proper separation of the larvae. The urogomphal prongs are most readily observed, but this character must be used with care because the tips of the prongs are sometimes worn off.

Urogomphi with tips of outer prongs either bluntly rounded (*opr*, figs. 13, *g*; 14, *j*); or sharp and inclined upward, inward or forward (figs. 13, *c*; 14, *i*); without spinelike setae (usually with a few very fine setae) on episterna of mesothorax and metathorax; abdominal mediotergites with prominent posterior setae not definitely "paired" (fig. 14, *d*) (species primarily predaceous)...................... 7

4\. Prongs of each urogomphus like grappling hooks (fig. 13, *e*); eyes usually small and indistinct.................................... 5

Urogomphal prongs of different type (fig. 13, *d*, *f*); eyes usually clearly visible 6

5\. Pleurites in first abdominal segment practically as long as sternal plate..............................**semivittatus** (Say) (?) (p. 66)

Pleurites in first abdominal segment less than three-fourths as long as sternal plate.......................the **edwardsi group** (p. 56)

6\. Urogomphi and prongs relatively short and thick (fig. 13, *d*, *i*); two pairs of lateroepicranial setae............the **aeripennis group** (p. 41)

Urogomphi and prongs relatively long and slender (fig. 13, *f*, *h*); only three prominent lateroepicranial setae......the **inflatus group** (p. 49)

7\. Ninth abdominal segment with prominent pits on dorsum (fig. 14, *j*); proxistipes and dististipes distinct (fig. 14, *h*).................. ....the **rotundicollis group** (p. 94)

Ninth abdominal segment lacking prominent pits (fig. 14, *i*); proxistipes and dististipes not distinct............................. 8

8\. Conspicuous color pattern on dorsum; urogomphi (fig. 14, *c*) with inner prongs (*ipr*) large and broadly rounded at tips............ ....**bipustulatus** (Linnaeus) (p. 106)

Without conspicuous color pattern; inner urogomphal prongs with sharp tips (*ipr*, fig. 14, *i*).................................. 9

9\. Outer prongs of urogomphi with sharp tip curving forward (*opr*, fig. 13, *c*); prongs subequal or outer prongs longer; only one "sensory" appendix on second segment of antenna............ 10

Outer prongs of urogomphi of different type (*opr*, fig. 13, *g*); prongs subequal or inner prongs longer; normally with more than one "sensory" appendix on second segment of antenna............. 11

10\. Ninth abdominal segment (fig. 14, *i*) with setae (usually four) on central dorsal area; head with dorsal posteroepicranial setae (*pcd*, fig. 10, *g*); nasale tridentate at tip........the **nitidulus group** (p. 111)

Ninth abdominal segment without setae on central dorsal area; head without dorsal posteroepicranial setae; nasale unidentate....... ....the **propola group** (p. 67)

11\. Abdominal mediotergites (fig. 14, *d*) with impressions (*im*) extending to mediodorsal suture on second to fifth segments; nasale unidentate; larvae yellowish brown......the **triundulatus group** (p. 75)

Abdominal mediotergites with transverse branch of impressions extending about three-fourths of distance from longitudinal branch to mediodorsal suture; nasale tridentate at tip; larvae brown to dark brown..................................the **fallax group** (p. 82)

12\. Presternum of prothorax divided into 2 or more sclerites (*prst*, figs. 10, *d*; 13, *a*).. 13

Presternum of prothorax (fig. 13, *b*) undivided, of 1 large triangular sclerite, sometimes rather deeply incised on lateroposterior aspects.. 15

13. Spiracles in eighth abdominal segment (*sp*, fig. 14, *f*) situated relatively much farther caudad than in seventh abdominal segment; abdominal pleurites well developed.............. **sjaelandicus** (Müller) (p. 142)
Spiracles in same relative position in all abdominal segments; abdominal pleurites small and indistinct.................................... 14
14. Spinelike setae present (usually 2 to 4) on episterna of mesothorax and metathorax; urogomphi (fig. 14, *g*) as figured.................... ....the **cupreus** group (p. 124)
Without such spinelike setae; urogomphi (fig. 14, *a*, *b*) as figured.... ....**appressus** (Randall) (p. 135)
15. Spiracles in eighth abdominal segment (*sp*, fig. 11, *e*) at least twice as long as spiracles in seventh abdominal segment.................... ....the **pyrrhos** group (p. 147)
Spiracles in seventh and eighth abdominal segments subequal in size.... 16
16. Dorsum of ninth abdominal segment (fig. 11, *f*) with blunt "teeth" (*to*) on lateral aspects, and with median groove (*mg*); eyes present ....**resplendens aerarius** (Randall) (p. 136)
Dorsum of ninth abdominal segment (fig. 11, *h*) with sharp "teeth" (*to*) laterally, and without median groove; eyes absent............ ....the **limoniiformis** group (p. 150)

THE LUDIUS AERIPENNIS GROUP

FIGURES 1-7, 9, *h*, *j*; 10, *d*; 13, *d*, *i*; 14, *e*; 15

KEY TO SPECIES

1. From North America.. 2
From Europe or Asia.. 4
2. With 4 setae on central dorsal area of ninth abdominal segment (fig. 15, *a*) ....**pruininus** (Horn) (p. 45)
Without such setae (fig. 7, *a*).. 3
3. Western North America....................**aeripennis** (Kirby) (p. 42)
Eastern North America............**appropinquans** (Randall) (?) (p. 44)
4. With 2 setae on central dorsal area of ninth abdominal segment (fig. 15, *f*) ....**latus** (Fabricius) (p. 48)
Without such setae..........................**aeneus** (Linnaeus) (p. 46)

Larvae of this group are known for the five species listed in the key above. With the exception of *appropinquans*, which was collected from leaf litter, all are soil inhabiting, preferring well-drained soils, and are extremely important pests, especially of grain crops. The larval life lasts for at least 3 years. Pupation occurs normally in July or early August. The adults are fully formed within 2 to 4 weeks after pupation occurs, but they usually remain in their pupal chambers until the following spring.

This group belongs to that larger association of *Ludius* that combine a large caudal notch and a divided prosternum. Closely related species are found in the *inflatus* group, but separation is readily

achieved through characters of the ninth abdominal segment (figs. 7, *a;* 15, *a, f;* 16, *a*), impressions on the mesothorax and metathorax, and through other differences discussed under the *inflatus* group (p. 49).

When mature, the larvae usually exceed 17 mm. in length. Dorsum yellowish brown to bright yellow. Caudal notch large, U-shaped. Urogomphi bifid, short and thick; prongs subequal in length with sharp, horny tips; tip of outer prong usually inclined backward, but not continuing downward as in the *edwardsi* group. Ninth abdominal segment with 3 or 4 prominent blunt tubercles or "teeth" on lateral margins of dorsal plate, no setae or 2 or 4 setae on central dorsal area, and distance between caudal notch and pleural area equal to one-sixth to one-fifth total length of segment exclusive of urogomphi. Nasale unidentate. Frontoclypeal area truncate posteriorly. Eyes well developed. Two pairs of lateroepicranial setae on each gena. Gula short and wide. Mandibles robust, as in figure 2, *e, f, h*. Second segment of antenna with one "sensory" appendix. Basal segment of labial palpi without setae. Presternum of prothorax divided into 3 or 4 sclerites. Mesothorax and metathorax with short impressions (indistinct in *pruininus*) on mediotergites, and with several spinelike setae (up to 10) on each episternum. Mediotergites of second to eighth abdominal segments with transverse branches of impressions usually attaining less than one-half of distance from longitudinal branches to middorsal suture, and with prominent setae arranged in pairs. Spiracles in anterior parts of segments.

LUDIUS AERIPENNIS (Kirby)

FIGURES 1-7; 9, *h, j;* 10, *d;* 13, *d;* 14, *e*

Elater aeripennis KIRBY, *in* Richardson's Fauna Boreali-Americana, vol. 4, p. 150, 1837.
Corymbites tinctus LECONTE, Proc. Acad. Nat. Sci. Philadelphia, p. 85, 1859.
Ludius elegans SCHWARZ, Wytsman, Genera Insectorum, pp. 46, 225, 322, 1907.
Ludius aeripennis (Kirby), BROWN, Canadian Ent., vol. 67, pp. 127-129, 1935.

This western species ranges from Alaska to Oregon and as far east as Manitoba and the Dakotas, probably including western Minnesota. The subspecies *destructor* Brown (Brown, 1935b, p. 129), referred to in the earlier economic literature as *tinctus* (LeConte) or as *aeripennis* (Kirby), is widespread and abundant over the prairie areas and adjoining parklands, but is replaced by the typical *aeripennis* in the forested and mountainous regions to the north and west. Both subspecies occur in the Peace River area of Alberta and British Columbia, *destructor* predominating in the open grassland sections.

The typical *aeripennis* has been associated with damage to wheat in the Peace River Block and is a pest, especially of truck crops, along the Pacific coast and in the inland mountain valleys. In northern Saskatchewan forests the larvae have been collected in moist sandy soil just under the surface litter and have been associated with plant injury when such areas have been brought under cultivation.

The subspecies *destructor* is a major pest in fields (King, 1928, pp. 702-703; King et al., 1940) and gardens (Glen and King, 1938; Munro and Schifino, 1938), the larvae being most abundant in loam or silty soil and in fields which have been cropped to grains or grasses for 5 or more years without summer-fallowing. Irrigated land in southern Alberta is less severely infested with this wireworm than is unirrigated land. Although primarily phytophagous, the larvae have been found attacking inactive stages of various insects including prepupal larvae of the sugar-beet webworm, *Loxostege sticticalis* Linnaeus, and egg pods of the grasshoppers *Camnula pellucida* Scudder and *Melanoplus* spp. In captivity, cannibalism occurs if the larvae are overcrowded. Strickland (1935, pp. 521-524; 1939; 1942) discusses the biology of this species and reports the larval period as varying from 3 to 10 years and the number of larval instars as ranging from 10 to at least 24. Rearing studies conducted at the Saskatoon laboratory have shown pupation to occur in the field from July 11 to August 8, most commonly in late July. Under laboratory conditions the pupal period usually lasts from 2 to 3 weeks. The pupal chamber is an unlined, irregular, earthern cell, commonly subovate, measuring from 9 to 10 mm. by 18 to 22 mm.; usually it is formed within 3 inches of the soil surface.

In addition to the primary features of the *aeripennis* group, the most important characters for the identification of the larva of *Ludius aeripennis* are: Ninth abdominal segment (figs. 6, *d*; 7, *a*, *d*) without setae on central dorsal area and with broad, rounded "teeth" (*to*) on sides of dorsal plate, and abdominal mediotergites (*mtg*, fig. 6, *a*, *c*) with transverse branches of impressions on second to eighth segments reaching approximately one-third of distance from longitudinal branches to middorsal suture. In structure, the two subspecies are indistinguishable except by size. The typical *aeripennis* larva attains a length of 27 or 28 mm. and a width of 3.75 mm.; *destructor* rarely exceeds 22 mm. in length and 3 mm. in breadth. The eastern North American *appropinquans* (Randall) and the European *aeneus* (Linnaeus) are so similar that constant structural differences have not been found and separation is most readily made on the basis of distribution.

A detailed description of the mature larva of *L. aeripennis destructor* Brown is given on pages 19-29. A general description was published by the writer in 1935 and prior to that the larva was figured by Strickland (1926, p. 7, fig. 1).

Material used in study.—Sixteen examples of the typical *aeripennis* and 36 of the subspecies *destructor* were examined. This material included the cast skins of 7 reared specimens of the typical form and 6 of *destructor*. Reared adults were all identified by W. J. Brown, Ottawa, Ontario.

L. aeripennis aeripennis (Kirby): To avoid misidentification, at least one specimen was reared to the adult state from each of the four groups of material selected for use in the present study.

4; Stump Lake, Saskatchewan; May 20, 1935; 2 reared adults emerged May 1, 1936, and July 4, 1936; B. Rysstad. (C.N.C.)
5; Dawson Creek, British Columbia; July 1935; a reared adult emerged June 2, 1936; K. M. King. (C.N.C.)
5; Tacoma, Wash.; Sept. 26, 1934; 2 reared; M. W. Stone. (C.N.C.)
2; Kirkland, Wash.; Aug. 30, 1933; 2 reared; E. W. Jones. (U.S.N.M.)

L. aeripennis destructor Brown: During the past 10 years large numbers of larvae of this species have been examined. However, in the present study careful examination was limited to approximately 36 specimens. These were from Saskatchewan (26) and Alberta (10). Twenty-seven specimens were collected from areas where the typical *aeripennis* has never been found. The other 9 were from the Peace River area of Alberta, but identification was confirmed by rearing. All this material is in the Canadian national collection. Separate collections for which associated reared adults are available are listed below.

20; Swift Current, Saskatchewan; June 1935; 4 reared adults emerged Aug. 27, 1935, May 4, 1936, and 2 on May 21, 1936; R. Glen and V. L. Berg.
4; Beaverlodge, Alberta; July 1935; 1 reared adult emerged Aug. 17, 1935; K. M. King.
5; Clairmont, Alberta; July 1935; 1 reared to adult Mar. 30, 1936; K. M. King.

LUDIUS APPROPINQUANS (Randall) (?)

Elater appropinquans RANDALL, Boston Journ. Nat. Hist., vol. 2, p. 5, 1838.
Ludius appropinquans (Randall), BROWN, Canadian Ent., vol. 67, pp. 130-131, 1935.

According to Brown (1935b, p. 131) this eastern North American species is distributed from central Manitoba and Wisconsin to the Atlantic coast. It is a forest species, occurring in the decomposing litter and under the bark of decayed coniferous logs and stumps.

The larvae are believed to be predaceous, feeding upon the cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig), being reported in a personal communication from R. F. Morris, Fredericton, New Brunswick.

In structure, the larva is identical with that of *L. aeripennis* and *L. aeneus* and separation is most readily secured through differences in distribution.

Material used in study.—Three larvae were examined. These were not identified through rearing, but were collected from litter under spruce in Sunbury County, New Brunswick. On the basis of structure these larvae belong unquestionably to the *aeripennis* group and the locality fits the known distribution of *appropinquans*. (Canadian national collection.)

LUDIUS PRUININUS (Horn)

FIGURES 13, *i*; 15, *a-c*

Corymbites pruininus HORN, Trans. Amer. Ent. Soc., vol. 3, p. 320, 1871.
Ludius pruinosus SCHWARZ, *in* Wytsman's Genera Insectorum, pp. 46, 226, 1907.
Corymbites noxius HYSLOP, Proc. Biol. Soc. Washington, vol. 27, p. 69, 1914.
Ludius pruininus (Horn), BROWN, Canadian Ent., vol. 67, p. 135, 1935.

The range of *pruininus* is indicated by Brown (1935b, p. 135) as bounded by Nebraska, California, and the Okanagan Valley of British Columbia. Lane (1925, p. 91; 1935, pp. 529-530) states that the distribution is governed by rainfall, the species occurring only on the semiarid sagebrush and bunchgrass regions which have an annual rainfall not exceeding 15 inches. This species is a serious pest of grain crops in the dry-farming districts of the area, but disappears in a few seasons from fields brought under irrigation. According to Hyslop (1915a, p. 13) and Lane (1931, p. 5) pupation may occur during the third year of larval life or from one to several years later, probably depending upon environmental conditions. The pupal chamber is constructed from 4 to 8 inches below the soil surface, usually in the hard soil just below the tillage line.

The larva is figured by Hyslop (1915a, p. 12, fig. 4), but no detailed description or comparison with closely related species is given.

Ludius pruininus is readily distinguished from *L. aeripennis* by possessing the following characters of the ninth abdominal segment (fig. 15, *a*): Four setae on central dorsal area; narrower and sharper "teeth" (*to*) on sides of dorsum; and paramedial impressions (*pim*) on dorsal plate usually distinct posteriorly, although coming close together and sometimes lying within a shallow median concavity.

Largest larva examined measured 23 mm. in length and 3.25 mm. in breadth without being fully distended. Furcal pits (prothorax) deeper than in *aeripennis*. Transverse branch of impressions on first eight abdominal segments usually shorter than in *aeripennis*. Urogomphi (*ur*, fig. 15, *a*; fig. 15, *b*, *c*) and prongs exceedingly variable in size, shape, and presence of turbercles, but usually as described below. Inner prong (*ipr*) slightly more slender than outer prong, projecting caudad and slightly mediad, with rather long, sharp, upturned, horny tip; prominent tubercle (sometimes absent) on posteroventral aspect, usually not very conspicuous from dorsal view; several small setae and 2 or 3 prominent hairs ventrally, 1 of which arises near base of tubercle; 1 prominent seta on posterodorsal surface, anterad to tubercle. Outer prong (*opr*) projecting dorsad, usually slightly caudad, with sharp, horny tip inclining backward (sometimes straight); conspicuous sharp, horny, setiferous tubercle (*tub*) laterally just below base of prong; 1 prominent seta on anterolateral aspect, several smaller setae around distal part of prong. Caudal notch (*cn*) highly variable, usually U-shaped, about as long as broad, narrower posteriorly; sometimes much wider than long, or subovate and longer than wide.

Material used in study.—In all, 27 specimens were examined, including the larval exuviae of 4 specimens reared to adults. All material was from the State of Washington and is stored in the Canadian national collection and the U. S. National Museum. The reared adults were identified by both M. C. Lane, Walla Walla, Wash., and W. J. Brown, Ottawa, Ontario. Whole larvae from Ritzville were examined, but these were collected on a different occasion from those that were reared to adults as listed below.

4; Ritzville, Wash.; all reared to adults; M. C. Lane. (U.S.N.M.: Ritzville Laboratory No. 20, subnumbers -41A5, -42E2, -42F1, -42F6.)

LUDIUS AENEUS (Linnaeus)

Elater aeneus Linnaeus, Systema Naturae, ed. 10, vol. 1, p. 406, 1758.

Selatosomus aeneus (Linnaeus), Stephens, Illustrations of British entomology, Mandibulata, vol. 3, p. 268, 1830.

Ludius aeneus (Linnaeus), Boisduval and Lacordaire, Faune Entomologique des Environs de Paris, vol. 1, p. 666, 1835.

Aphotistus aeneus (Linnaeus), Kirby, *in* Richardson's Fauna Boreali-Americana, vol. 4, p. 149, 1837.

Corymbites (*Selatosomus*) *aeneus* (Linnaeus), Schenkling, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 370, 1927.

This common species is widely distributed in temperate and central Europe and in western Siberia. The larvae inhabit the soil of meadows, forests, and cultivated fields, preference being shown for drier locations and soils of a sandy texture. European literature is replete with references to *aeneus* as a major pest of cereals, root crops, potatoes, Jerusalem artichokes, legumes, tobacco, forest seedlings, and buddings in fruit nurseries. Ghilarov (1937, p. 636) considers this species to be almost purely phytophagous. However, Chrzanowski (1931) has observed the larvae to attack weakened or inactive insects, including moulting larvae of their own species.

The mature larva attains a length of 25 mm. when fully distended. It has been described from Denmark by Schiodte (1870, pp. 519-520) and Henriksen (1911, pp. 262-263), from France by Perris (1877, p. 180), and from Germany by Altum (1878, p. 74), Beling (1883, pp. 281-283; 1884, p. 204), and Horst (1922, pp. 32-35). *L. aeneus* is readily separated from the larva of *latus* through lack of setae on the central dorsal area of the ninth abdominal segment. However, structural characters fail to distinguish the larvae of *aeneus* and the American species *aeripennis* and *appropinquans,* and identification must be based primarily upon distribution. When compared with *aeripennis destructor,* the majority of the *aeneus* larvae examined had the anterior margin of the caudal notch straighter, the urogomphi slightly broader in relation to the width of the caudal notch, and the outer prongs of the urogomphi more nearly at right angles to the inner prongs. But all these characters failed when tested in an adequate series of specimens.

Both Schiodte and Henriksen refer to the musculature being visible through the integument. This was evident on very few of the specimens examined in the present study and is believed to be an atypical condition probably resulting from desiccation or action of the preserving medium.

Material used in study.—Including some specimens that were available to K. L. Henriksen at the time he described this species, 22 larvae were examined. The material was collected in Finland (2), Denmark (8), Germany (8), and Italy (4). Reared adults and larval exuviae of reared specimens were not available. However, there is every reason to believe that the material used is definitely *Corymbites* (*Selatosomus*) *aeneus* (Linnaeus), as recognized by European entomologists, and is the larva referred to by that name in current entomological literature. The specimens examined are at present in the Canadian national collection (6), the U. S. National Museum (9), the British Museum (3), and the private collection of Dr. van Emden (4).

LUDIUS LATUS (Fabricius)

FIGURE 15, *d-f*

Elater latus FABRICIUS, Systema Eleutheratorum, vol. 2, p. 232, 1801.
Ludius latus (Fabricius), BOISDUVAL and LACORDAIRE, Faune Entomologique des Environs de Paris, vol. 1, p. 667, 1835.
Diacanthus latus (Fabricius), GERMAR, Zeitschr. fur die Ent., vol. 4, p. 77, 1843.
Corymbites (*Selatosomus*) *latus* (Fabricius), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 370, 1927.

This species is a well-known pest from France to the Far Eastern area of Siberia. Crops attacked include cereals, vegetables, tobacco, chufa (*Cyperus esculentus* Linnaeus) and rubber-producing plants. In general, *latus* appears to inhabit typical "steppe" and "forest-steppe" areas. However, the preferred native habitat appears to be unknown. Regnier (1921) observed the species to be more dangerous in recently cleared land in France, but Beĭ-Bienko (1936) found relatively few larvae in virgin soil in the Orenburg district of western Siberia. Russian writers are in general agreement that *latus* is most abundant in abandoned fields, especially in land overgrown with *Agropyron, Artemisia,* and *Bromus,* and least abundant in fields that recently have been in clean fallow. Pilyugina (1937) found infestations of this species to be more severe on unirrigated fields than on irrigated tracts, and Semenov (1931) reports infestations to be heavier on the higher parts of tobacco fields. Thus, it would appear that *latus* prefers dry locations. Masaitis (1929) reports pupation as occurring at a depth of from 3 to 6 inches below the soil surface.

The larva has been described at length by Perris (1877, pp. 177-179), who failed to find differences from the larva of *aeneus;* Masaitis (1931) compared *latus* and *spretus;* and Rambousek (1928) referred briefly to *latus* in his key, but did not make comparisons with closely related species. Znamensky (1926, 1927) separates *latus* and *aeneus* in his illustrated keys, *latus* usually being dark reddish yellow and bearing well-defined tubercles ventrad to bases of urogomphal prongs, *aeneus* usually pale yellow and bearing small, indefinite turbercles ventrad to bases of urogomphal prongs.

Larvae examined in the present study measured up to 24 mm. in length and 3.0 mm. in width. The larva is very similar to that of *aeripennis* and *aeneus,* but, on the basis of the material at hand, differs in possessing the following characters: 2 setae on the central dorsal area of the ninth abdominal segment (fig. 15, *f*) ; transverse branches of the impressions on the first 8 abdominal segments slightly longer

than in *acripennis destructor* (fig. 6, *a*, *c*) and on the ninth abdominal segment continuing clearly across the dorsum; subnasale worn on specimens examined, but giving indications of about 12 denticles on the serrate ridge. The material examined showed no distinct color differences from *aeneus*. Somewhat larger tubercles, as indicated by Znamensky, undoubtedly occur in specimens entirely free from erosion, but this character is believed to be very variable and should be used only to supplement the characters given above.

Material used in study.—Three larvae were examined. All were collected at Chuchkova, Moscow District, Russia, 1936, and were identified by M. Ghilarov. It is not known if the identification was supported by rearing. (U. S. National Museum collection.)

THE LUDIUS INFLATUS GROUP

FIGURES 13, *f*, *h*; 16, *a*

KEY TO SPECIES

1. Transverse branches of impressions on the mediotergites of second to eighth abdominal segments reaching from one-eighth to one-sixth of the distance from longitudinal branches to mediodorsal suture; western North America....................**glaucus** (Germar) (p. 50)
   Transverse branches of impressions reaching from one-fifth to one-fourth of distance to dorsal suture; eastern North America.............. ....**inflatus** (Say) (?) (p. 55)

Knowledge of this group is based upon the larva of *glaucus* (Germar) and specimens from Urbana, Ill., which are probably *inflatus* (Say). Both species are soil inhabiting; their larvae have been confused and commonly referred to in the economic literature under the one name, *inflatus*.

This group is very closely allied to the *aeripennis* group, differing as follows: caudal notch subcircular or subovate; urogomphi and prongs relatively longer and more slender, bearing larger toothlike tubercles; ninth abdominal segment with 2 or 3 sharp "teeth" on lateral margins of dorsum, without setae on central dorsal area, and distance between pleural area and caudal notch equal to one-fifth to one-fourth length of segment exclusive of urogomphi; 3 latero-epicranial setae on each gena, arranged as 1 pair with an unpaired hair farther ventrad; without definite impressions on mediotergites of mesothorax and metathorax.

LUDIUS GLAUCUS (Germar)

FIGURES 13, *f*, *h*; 16, *a*

Diacanthus glaucus GERMAR, Zeitschr. fur die Ent., vol. 4, p. 76, 1843.
Hadromorphus similissimus MOTSCHULSKY, Bull. Soc. Moscou, vol. 32, p. 374, 1859.
Ludius glaucus (Germar), BROWN, Canadian Ent., vol. 68, p. 135, 1936.

The distribution of this western species is indicated by Brown (1936c, p. 135) as extending from Utah to California and north to southern Alberta and the Okanagan Valley of British Columbia. The author has found the larvae in grain fields in southwestern Alberta and along the foothills of the Rocky Mountains as far north as Calgary. Essig (1926, p. 394, "*inflatus*") reports the species in Arizona and New Mexico. Under the name of *inflatus* Say, the larva has been recorded as an important pest in Washington, Oregon, Idaho, and Montana. The crops most frequently injured are wheat, corn, and potatoes. Lane (1925, p. 91) reports that the species inhabits areas where the annual rainfall exceeds 15 inches, and Hyslop (1915a, p. 10) describes the typical native habitat as one of bunchgrass (*Agropyron spicatum*) and June grass (*Poa secunda*) but lacking in sagebrush.

According to Hyslop (1915a, p. 11), the normal larval period is 3 years, pupation occurring in late June and early July. However, a specimen collected in May and reared by the writer did not pupate until August. The oval pupal cell measured 13 mm. by 6 mm. The transformation to the adult state is completed within 2 or 3 weeks and the beetles overwinter in their pupal chambers.

Distribution and slight differences in sculpture serve for the distinguishing of the larvae of *glaucus* and the closely related *inflatus*.

Description of "mature" larva.—Length 16 mm., greatest breadth 2.6 mm. on fourth and fifth abdominal segments. A fully distended larva measured 18.5 mm. Body robust; with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about three-fourths greatest body width. Dorsum pale yellow (pale "yellow ocher," Ridgway, 1912) to very light brown; venter slightly paler. Dorsum bearing fine punctures, increasing in abundance on the more posterior segments.

Head subquadrangular with arcuate sides, flattened above and below.

Frontoclypeal region with posterior part extending backward to or almost to foramen magnum, truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale unidentate, terminating sharply when uneroded. Subnasale consisting

of transverse ridge, anteriorly convex; serrate, when uneroded, with about 7 subequal short, sharp, forward-projecting denticles. Paranasal lobes produced beyond nasale, each bearing 2 prominent setae and 2 to 4 minute setae.

Epicranial plates sparsely and finely punctulate. Dorsal sulci shallow, each bearing 5 setae subequally spaced, the most anterior seta being very long, the next seta minute and sometimes wanting, the 3 most posterior setae small. Ventral sulci bearing row of 7 to 10 setae, usually about 2 to 4 conspicuous. Three large lateroepicranial setae arranged as a dorsal pair and an unpaired ventral seta, usually with 1 or more small or minute setae caudad to unpaired hair. Eye spot black, well defined, ovate or circular; surrounded by 3 setae, rarely with an additional extremely minute seta. Postgenal areas expanded mesad, but always rather widely separated; glabrous.

Gula short, relatively wide; glabrous.

Antennae with first joint weakly clavate, two-thirds as wide as long; without setae; 3 or 4 small pores. Second segment subcylindrical, almost as wide as long; one-half length of basal joint; 1 or 2 pores; a few small "sensory" pegs borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, about one-half as long as second joint and one-quarter to one-third as wide; 4 setae on apex.

Mandibles of moderate length, robust; about three-fifths to five-sevenths as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending, pointed; outer surface convex with deep dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts only about three-fourths as wide across bases of stipites as at anterior ends of stipites. Cardines well separated. Stipes large; proxistipes and dististipes not distinct; usually 4 or 5 prominent setae on antero-lateroventral aspect, sometimes also 1 or 2 smaller hairs. Galea with basal joint subcylindrical, slightly shorter than terminal joint; without setae; 2 or 3 faint pores. Terminal segment narrower than basal segment, outer margin longer than inner margin, with 7 to 9 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment wider than long; distally on mesoventral surface with group of 4 or 5 small pores and 1 relatively large and 1 smaller seta. Second segment wider than long; as long as first joint and about as wide; without setae; with 4 or 5 pores. Third joint wider than long; about one-half length of second seg-

ment; 2 pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 near lateral aspect. Fourth segment as long as wide or slightly longer than wide; about as long as third joint; 1 minute seta near middorsal aspect. Postmentum with 1 long seta near each corner, few minute pores scattered over surface. First prementum with 3 to 5 large setae just caudad to base of each palpus, forming transverse row of 6 to 10 hairs. Labial palpi with basal segment cylindrical, one-half length of first prementum, as long as wide, without setae, bearing up to 7 pores; terminal segment shorter than basal joint and about one-half as wide, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites with scattered small shallow pits; anteriorly with 7 to 9 setae (on each side of median dorsal suture) in transverse row, usually arranged as follows: the 2 most medial setae always paired, the next 1 or 2 setae unpaired, then a group of 3 setae and finally 1 unpaired seta considerably farther laterad; posteriorly with 5 to 8 (usually 6 or 7) setae in transverse row arranged as 3 pairs subequally spaced, or as 2 pairs with a group of 3 setae between, sometimes with 1 additional small seta between each pair and slightly farther caudad; glabrous elsewhere. Episternum with 1 large and 2 small setae. Epimeron bearing 1 prominent seta and 1 to 3 small or minute setae. Presternal area consisting of 4 sclerites as follows: a small posterior median sclerite, anteriorly attenuate; 2 large subtriangular lateral sclerites, each striate on anterolateral aspect, with 1 stout seta laterad to center and a diagonal row of 5 minute setae or pegs on anteromedial aspect. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites punctulate; impressions indistinct, reduced to short row of small pale pits. Anterior part of each mediotergite with 1 seta, near lateral margin; 1 pair large setae farther caudad along lateral margin; posterior part of mediotergite with 2 pairs conspicuous setae and sometimes 1 or 2 additional small hairs; minute setae sometimes observable in some of pits. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Each episternum bearing up to 11 spinelike setae (usually 6 or 7). Eusternum with transverse row of 4 to 6 fine setae. Mesothoracic spiracle subequal in size to spiracles in abdomen.

Legs subequal in length. Coxa with up to 50 (usually 25 to 45) spinelike setae on anterior aspect; 4 or 5 stout setae and a few scattered fine hairs on posterior surface. Trochanter less than one-half

length of coxa; with 6 to 9 spinelike setae on medioanterior surface; 6 to 9 such setae and 1 fine seta scattered on posterior surface; 2 well-developed setae on medial aspect. Femur usually with 6 to 10 spinelike setae on medioanterior surface; 5 or 6 spinelike setae and 1 slender seta on posterior surface; 1, rarely 2, long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 5 or 6 setae around distal margin; 3 to 5 spinelike setae and one slender seta on medioanterior surface; 3 to 5 spinelike setae on posterior surface. Ungula, when uneroded, about as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites with small, shallow punctures, becoming denser from first to eighth segment; impressions not conspicuous, very small on first segment; transverse branch slightly sinuate, on second to eighth segments extending one-eighth to one-sixth distance from longitudinal branch to middorsal suture; longitudinal branch of impression extending from one-half to three-fifths distance from transverse branch to posterior transverse row of setae, longer on more posterior segments. Anterior part of mediotergite without setae, except for an extremely minute seta sometimes observable near medial end of impression; 2 semipaired setae along lateral margin, just anterad to middle of segment; posterior part of mediotergite, with transverse row of 6 setae, arranged as 3 pairs, sometimes 1 or 2 very small setae close to the paired hairs. Laterotergite I extending length of segment; with 1 to 3 setae. Spiracular sclerite small, subovate, becoming longer and narrower in the more posterior segments; in the eighth segment very little wider than spiracle, but about 3 times as long; always in anterior half of segment. Spiracles subequal in length, in extreme posterior part of spiracular sclerite. Pleurite large, subovate or subtriangular, with 3 or 4 setae. Sternum of 1 piece, subquadrate, narrower opposite pleurite; with 4 faint longitudinal impressions, a lateral pair and a paramedial pair which meet posteriorly; bearing up to 12 setae, mostly near margins of sclerite.

Ninth abdominal segment (fig. 16, *a*), exclusive of urogomphi, as long as, or slightly shorter than, eighth abdominal segment and four-fifths as wide; four-fifths as long as wide; sides of anterior half subparallel, posterior half tapering caudally, making width at anterior margin of caudal notch about three-fifths to two-thirds greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; densely punctulate; 4 faint longitudinal

impressions, 2 laterally and a paramedial pair which converge posteriorly sometimes meeting in a median groove; without setae except at lateral margins, which are slightly raised and carinate, bearing 3 small, sharp "teeth" (*to*) (the most anterior very small, most posterior largest), each with 1 long bristle; a fourth "tooth" is situated farther caudad and ventrad; transverse impression wanting. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 16 to 28 setae on each side, some issuing from small sclerotized tubercles; lateral aspect usually moderately densely punctulate. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fifth to one-fourth total length of segment (exclusive of urogomphi). Pleural area large, consisting of transversely striated membrane except at anterior ends where small ovate pleurites. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite with from 8 to 14 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 16, *a*; fig. 13, *f*) well developed, separate, bifid; directed dorsocaudad; prongs well developed, subequal; urogomphi and prongs long and relatively slender. Inner prong (*ipr*) directed mesocaudad and slightly dorsad, terminating in sharp, upturned horny point; prominent, sharp, toothlike tubercule (*tub*) on ventro-caudo-lateral aspect, halfway along prong; sometimes an additional small tubercle ventrally near base of prong; 3 large setae, one ventrally at base of prong, 1 from inner aspect and 1 from upper aspect of base of prominent tubercle; usually 2 or 3 smaller setae issuing from prong near base of large tubercle. Outer prong (*opr*) somewhat corniform; directed dorsad, and usually slightly caudad with sharp tip turned posteriorly; large, horny tubercle (*tub*) with sharp upturned point situated laterally just below base of prong; usually with 3 large setae, 1 from anterolateral aspect, about halfway along prong, 2 from near upper aspect of base of tubercle; several small, fine setae scattered over distal half of prong, most abundant on posterior surface at point where prong distinctly becomes narrower. Undivided part of urogomphus about as long as divided portion; without setae except as noted above. Caudal notch (*cn*) large, shape variable, but usually subcircular; about as broad as long, somewhat narrowed posteriorly.

Tenth abdominal segment with 1 whorl (sometimes 2 whorls) of 10 fine setae; anal aperture linear and median.

Material used in study.—Twenty-two specimens were examined, 3 from Alberta and 19 (U. S. National Museum collection) from the State of Washington. The latter were received through the courtesy

of M. C. Lane, who obtained larvae from mated adults that he personally identified. The parent adults apparently were not retained.

3; Bradshaw, Alberta; May 28, 1942; 1 reared to adult Aug. 10; R. Glen (C.N.C.).

LUDIUS INFLATUS (Say) (?)

Elater inflatus SAY, Ann. Lyc. Nat. Hist. New York, p. 258, 1825.—LECONTE, Complete writings of Thomas Say, vol. 1, p. 392, 1859.
Elater metallicus SAY, Ann. Lyc. Nat. Hist. New York, p. 258, 1825.
Ludius inflatus (Say), BROWN, Canadian Ent., vol. 68, p. 134, 1936.

According to Brown (1936c, p. 135), *inflatus* is an eastern species, adults being known from South Carolina to southern Quebec and Ontario and as far west as Indiana.

Blatchley (1910, p. 767) found the adults in low open woods, but the larval habitat has not been described. However, larvae believed to be of this species were taken from soil in the "University Woods," an elm-maple forest located about 5 miles northeast of the campus of the University of Illinois. Describing the "University Woods," Weese (1924, p. 8) states, "The drainage is poor, so that in wet seasons the soil becomes saturated with moisture, and water may stand for some time in the Spring in depressions even in the higher parts of the woods. The soil is yellow-gray silt loam, an upland timber soil." This area has an average annual rainfall believed to be in excess of 35 inches.

These facts suggest that *inflatus* is primarily a forest or parkland species, probably restricted to well-watered soils. There are no published records of *inflatus* (sensu stricto) causing injury to cultivated plants.

Structurally the larva of *inflatus* is very similar to that of *glaucus*. On the basis of the rather inadequate material that was available for study, the two species may be separated as follows: in *inflatus* the punctation is slightly less conspicuous, and the transverse branches of impressions on the abdominal mediotergites are slightly longer. In *glaucus* the transverse branch of each impression reaches from one-eighth to one-sixth the distance from the longitudinal branch to the mediodorsal suture, in *inflatus* from one-fifth to one-fourth that distance.

To determine the constancy and reliability of the above differences it will be necessary to obtain additional material, the greatest need being for *inflatus* larvae identified through rearing. At present, the principal reliance in the identification of these species must be upon geographic distribution.

Material used in study.—Only two specimens, from the "University Woods," Urbana, Ill., were used in the present study. These were not associated with reared adults and were identified primarily through their eastern locality. On the basis of adult characters, Brown (1936c) indicates that *L. inflatus* (Say) is the only eastern species closely related to *L. glaucus* (Germar). The larvae examined are deposited in the Canadian national collection.

* * *

THE LUDIUS EDWARDSI GROUP

FIGURES 13, *e*; 16, *c, d, f*

KEY TO SPECIES

1. From North America 2
   From Siberia .... **spretus** (Mannerheim) (p. 63)
2. Urogomphal prongs (fig. 16, *c*) relatively straight, with short, curved tips; full-grown larvae exceed 20 mm. in length; in forest areas.... ....**Ludius cruciatus festivus** (LeConte) (?) (p. 62)
   Urogomphal prongs (fig. 16, *d*) curved, with long, curved tips; full-grown larvae do not exceed 16 mm. in length; in prairie and open parklands .... **sexualis** Brown (?) (p. 57)

On the basis of larval characters, three species have been included in this group, namely, the Siberian *spretus* (Mannerheim), the North American *sexualis* Brown, and an unidentified species.

It is possible that the unidentified larvae are *Ludius cruciatus festivus* (LeConte), which occurs in wooded areas of western North America. On the basis of adult characters, Brown (1935a, pp. 1-3) places the European *cruciatus* (Linnaeus) and its American subspecies in the *cruciatus* group, which is closely allied to the *edwardsi* group. Whether this distinction is supported by larval characters cannot be determined without accurately identified larval material. However, the larvae of both *spretus* and *sexualis* inhabit the soil of prairie and parklands whereas the larvae here regarded as *cruciatus festivus* are found in forest soil.

Larvae of the *edwardsi* group are known to injure cultivated crops, especially cereals.

This group is characterized as follows: The body is widest in the region between the mesothorax and the third abdominal segment, the ninth abdominal segment is subquadrate (fig. 16, *f*), the urogomphi resemble grappling hooks (fig. 16, *c, d*), and the pleurites in the anterior abdominal segments are less than three-fourths as long as the

sternum. Very close allies are found in the *semivittatus* group for which very inadequate larval material is at hand.

The larvae of the *edwardsi* group are bright yellow. Caudal notch large, broadly U-shaped or transversely ovate. Urogomphi short, thick, with subequal prongs terminating in rather long, sharp, horny tips giving appearance of grappling hooks; tip of outer prong curving backward and downward; no prominent tubercles on prongs. Ninth abdominal segment with 1 to 3 small, blunt tubercles or "teeth" on each lateral margin of dorsum; 4 or more setae on central dorsal area; and distance between pleurite and caudal notch about one-tenth to one-eighth of total length of segment, exclusive of urogomphi. Nasale typically of 1 large median tooth with a small denticle on each side of base, lateral denticles sometimes lacking. Frons truncate posteriorly, extending to or almost to foramen magnum. One "sensory" appendix on second segment of antenna. Eyes usually present, but often small and inconspicuous. Basal segment of labial palpi with 1 seta ventrally. Gula short and wide. Mandible somewhat concave dorsally on distal half. Presternum of prothorax divided into 3 or 4 sclerites. Mesothorax and metathorax with indistinct impressions on mediotergites; and each episternum bearing spinelike setae varying in number to a maxium of 5; mediotergites of second to eighth abdominal segments with transverse branch of impressions extremely short, almost wanting; and with most conspicuous setae arranged in pairs, each pair consisting of 1 short and 1 long seta. Pleurite on first abdominal segment less than three-fourths as long as sternum.

LUDIUS SEXUALIS Brown (?)

FIGURES 13, *e*; 16, *d*, *f*

Ludius sexualis BROWN, Canadian Ent., vol. 67, pp. 7-8, 1935.

Brown records this species from Saskatchewan, Alberta, and Wyoming, and states that it is evidently closely allied to the Siberian *spretus* (Mannerheim) and to the mountain-dwelling American *morulus* LeConte.

Larvae of *sexualis* have not been identified through rearing, but larval specimens have been collected at Saskatoon, Saskatchewan, the locality of the paratypes used by Brown in his description of this species, and these larvae bear obvious resemblance to Masaitis' (1931) figures and description of the larva of *Ludius spretus* (Mannerheim). Since there are no other unidentified larvae of *Ludius* occurring in the Saskatoon district with which these specimens might be confused, it is believed that their identity is quite reliably established.

Ludius sexualis is evidently a plains species. In native situations it is associated with prairie grasses, especially with mixed grass and silverberry (*Elaeagnus*) and to a lesser degree with the grassy margins of snowberry (*Symphoricarpos*) thickets. It persists for many years after such areas have been brought under cultivation. The species has been found in some abundance in a few old bromegrass fields which originally contained large areas of snowberry. Larvae have been taken at depths ranging from near the soil surface to 22 inches. King (1928, p. 705, "*Ludius* (?) sp.") lists *sexualis* among the wireworms of lesser economic importance in Saskatchewan.

The larva strongly resembles that of a much larger unidentified species (possibly *cruciatus festivus* LeConte), from which it may be distinguished by size, the urogomphi (fig. 16, *c, d*), and the habitat.

Description of "mature" larva.—Length 16 mm., when fully distended; greatest breadth 1.6 mm. None of the specimens examined were larger. Segments usually subequal in width, sometimes wider in region of mesothorax, metathorax, and first to third abdominal segments. Body moderately robust; with moderately large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about four-fifths greatest body width. Dorsum pale yellow or light brown (near "cinnamon-buff," Ridgway, 1912); mouthparts and prongs of urogomphi darker, head and prothorax sometimes slightly darker; venter slightly paler. Dorsum slightly rugose; scattered minute, shallow pits usually observable on some segments.

Head subquadrangular with strongly arcuate sides; somewhat flattened above and below.

Frontoclypeal region with posterior part extending backward to foramen magnum; truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale consisting of large median tooth with a fine lateral projection on each side near base; lateral projections usually eroded away, giving nasale unidentate appearance. Subnasale indefinite and variable; usually without denticles; sometimes a few minute, sharp denticles arising from ventral surface of nasale almost halfway up median tooth, arranged in irregular transverse row. Paranasal lobes produced beyond nasale, each bearing 3 to 5 setae (1 or 2 small).

Epicranial plates with sparse, fine, inconspicuous punctures. Dorsal sulci shallow, each with 5 setae subequally spaced, the most anterior seta being long, others small. Ventral sulci bearing row of 5 to 7 setae, usually 2 to 5 conspicuous. Lateroepicranial setae include dorsal and ventral pairs (usually 1 large and 1 small seta in each pair) with 1

small seta anterad to dorsal pair and 2 or 3 minute setae in slight longitudinal depression posterad to ventral pair. Eye spot black; usually small and somewhat diffuse; ovate or circular; surrounded by 4 setae, sometimes 1 additional minute seta between eye spot and lateroepicranial setae. Postgenal areas expanded mesad, but well separated; glabrous.

Gula short, relatively wide; glabrous.

Antennae with first joint clavate, nearly as wide as long; without setae; 2 or 3 small pores. Second joint subcylindrical, about as wide as long; three-fifths length of basal joint; 1 or 2 pores, a few small pegs and setae borne distally, 1 laterad to, and almost as long as, "sensory" appendix; 1 medium-sized, conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, barely half as long as second joint and one-third as wide; 4 setae on apex.

Mandibles of moderate length, robust; two-thirds as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending, pointed; outer surface convex with long, shallow, dorsal groove; inner aspect sharp, convex ventrally, excavate dorsally.

Ventral mouthparts about three-fourths as wide across bases of stipites as at anterior ends of stipites. Cardines well separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 4 to 6 prominent setae on antero-lateroventral aspect. Galea with basal joint subcylindrical, slightly shorter than terminal joint, usually without setae or pores; terminal joint narrower than basal segment, outer margin longer than inner margin, 7 to 9 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment slightly wider than long; distally on mesoventral surface with group of 2 or 3 small pores and 2 setae. Second joint distinctly wider than long; slightly shorter than first joint; without setae; 3 or 4 pores. Third joint wider than long; at least two-thirds length of second joint; 2 pores ventrally; distally, 1 minute seta on mesoventral aspect and 1 near lateral aspect. Fourth segment as long as wide; about as long as third joint and at least one-half as wide; without setae; 1 pore. Postmentum with 1 long seta at each corner and 1 minute seta short distance caudad to each long anterior hair; few minute pores scattered over surface, 1 larger pore just anterad to each long anterior hair. First prementum with 1 large seta and sometimes also 1 smaller seta just caudad to base of each palpus. Labial palpi with basal joint about one-half length of first prementum, usually longer than wide, 1 small seta and 2 to 5 pores on ventral surface; terminal joint small, from one-half to two-thirds length and

about one-half width of basal joint; without setae; usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; only very slightly wider posteriorly; slightly wider than long. Tergites minutely punctulate; anteriorly with about 7 setae (on each side of median dorsal suture) in transverse row, usually arranged as 3 pairs (1 short and 1 long seta in each pair) and 1 unpaired seta farther laterad; posteriorly with 6 setae in transverse row arranged as 3 pairs (1 short and 1 long seta in each pair); usually 1 or 2 minute unpaired setae near center of sclerite. Episternum usually with 1 large and 1 or 2 smaller setae near center and a few minute hairs near margin adjacent to presternum. Epimeron with 1 or 2 minute setae. Presternal area consisting of 4 sclerites as follows: A small posterior median sclerite, anteriorly attenuate, bearing 2 fine setae anteriorly; 2 large subtriangular lateral sclerites striate on anterolateral aspect, with 1 stout bristle laterad to center and a diagonal row of 3 or 4 minute setae on anteromedial aspect; and a very narrow, median, anterior piece. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous or weakly sclerotized.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; impressions indistinct. Anterior part of each mediotergite with transverse row of 4 small unpaired setae, the most lateral seta largest; posterior part of each mediotergite with transverse row of 4 to 6 setae, arranged as 2 pairs (1 short and 1 long seta in each pair) and sometimes 1 or 2 unpaired setae; 1 pair of setae on lateral aspect of mediotergite; additional minute setae sometimes observable in punctures, especially in anterior part of sclerite. Anterior laterotergite subtriangular, almost one-half as large as subovate posterior laterotergite. Episternum bearing up to 5 (usually 3 or 4) spinelike setae. Mesothoracic spiracles about equal in size to or very slightly larger than spiracles in abdomen.

Legs subequal in length. Coxa usually with 20 to 30 spinelike setae on anterior aspect, mostly in 2 or 3 oblique rows; 1 or 2 stout setae and a few small, scattered hairs on posterior surface. Trochanter with 5 to 7 spinelike setae on medioanterior surface; 3 to 6 such setae and 1 or 2 fine setae scattered on posterior surface; 2 well-developed setae on medial surface. Femur usually with 4 to 8 spinelike setae on medioanterior surface; 2 to 4 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 5 or 6 setae around distal margin; 2 or 3 spinelike setae on medioanterior surface; 2 or

3 spinelike setae on posterior surface. Ungula, when uneroded, almost as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; first and second segments sometimes widest, but usually very little difference in width. Mediotergites with a few small, shallow, indistinct pits; transverse branches of impressions very short and indistinct, curving slightly backward; longitudinal branch of impression only a faint groove extending approximately one-half distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite with transverse row usually of 4 unpaired setae arranged as follows: most lateral seta largest, situated below impression; 1 at end of transverse branch of impression; 1 halfway between transverse branch and median dorsal suture; 1 tiny seta near dorsal suture; sometimes a few additional minute setae. Posterior part of mediotergite with transverse row of about 10 setae (fewer in first segment), 6 most conspicuous setae arranged as 3 pairs (1 short and 1 long seta in each pair), 1 small seta between pairs, 1 or 2 minute setae farther mediad than most medial pair, sometimes 1 minute seta laterad to most lateral pair. Lateral part of mediotergite with 1 or 2 small setae short distance caudad to most lateral seta in anterior row. Laterotergite I extending length of segment; bearing 4 to 6 setae, only 1 conspicuous. Spiracles subequal; borne in posterior part of small, ovate spiracular sclerite which is approximately twice length of spiracle and situated in anterior half of segment. Pleurite large, subtriangular; bearing 3 or 4 setae (only 1 long) on posterior half; definitely largest in first segment and smallest in eighth. Sternum of 1 piece, subquadrate, narrower posteriorly; usually bearing from 10 to 16 setae, mostly near lateral margins.

Ninth abdominal segment (fig. 16, *f*) exclusive of urogomphi, slightly shorter than eighth abdominal segment and almost as wide; three-fourths to four-fifths as long as wide; sides subparallel. Dorsum strongly convex; with minute, sparse punctures; 4 faint longitudinal impressions, 2 laterally and a paramedian subparallel pair; central area with 4 conspicuous setae (2 most posterior longer) and usually 2 to 6 small setae; lateral margins not well defined, almost lacking anteriorly, bearing 1 or 2 small, blunt, setiferous tubercles ("teeth") posteriorly and 1 or 2 unpaired setae farther forward; transverse impression short and very faint, almost wanting. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 20 to 30 setae on each side, nearly all in posterior half of segment. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth to one-tenth

total length of segment (exclusive of urogomphi). Pleural area large, consisting of transversely striated membrane except for small ovate pleurite at anterior ends. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite usually with from 10 to 15 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 16, *f*; fig. 16, *d*), separate, bifid, short, robust; prongs subequal, dark and horny, resembling grappling hooks. Inner prong (*ipr*) directed mediocaudad in horizontal plane, with sharp, horny point turning upward; small horny tubercle on caudolateral surface; usually 3 or 4 long setae and as many smaller setae arising from outer surface of prong; sometimes a few fine setae on inner aspect. Outer prong (*opr*) projected dorsad or caudodorsad and usually slightly mesad with long, sharp, horny point curving backward and usually slightly inward and downward; small tubercle laterally just at base of prong; 2 or 3 large setae, 1 issuing from anterior or anterolateral aspect, almost halfway up prong, 1 or 2 from base of turbercle; up to 10 smaller setae scattered over prong. Undivided part of urogomphus very short; thick; usually with a few fine short setae scattered over mesal, ventral, and lateral surfaces.

Caudal notch (*cn*) large, U-shaped or transversely subovate, wider than long, somewhat narrowed posteriorly by tips of inner prongs.

Tenth abdominal segment with a proximal whorl of about 20 fine setae and a distal whorl of 10 such hairs; anal aperture linear and median.

Material used in study.—Twelve specimens were examined. All were collected at Saskatoon, Saskatchewan, from native sod and cultivated fields. The species has not been reared and identification is based upon field association of adults and larvae and upon other evidence presented in the introductory paragraphs of the discussion of this species. (Canadian national collection.)

LUDIUS CRUCIATUS FESTIVUS (LeConte) (?)

FIGURE 16, *c*

Corymbites festivus LECONTE, Reports of explorations and surveys . . . from the Mississippi River to the Pacific Ocean, vol. 12, pt. 3, No. 1, p. 46, 1857.
Ludius cruciatus festivus (LeConte), BROWN, Canadian Ent., vol. 67, p. 3, 1935.

Unidentified larvae, obviously closely allied to *sexualis* Brown, were found in soil at Stump Lake in northern Saskatchewan. This collection was made in 1934 in a field which reportedly had been part of a spruce forest until 1926. These larvae were found together with

larvae of *Ludius aeripennis* (Kirby) and *Limonius pectoralis* LeConte and might have contributed to the damage to grain crops that was reported in connection with the infestation.

The material available for examination was limited to four specimens that were not in good condition, having died and desiccated before being placed in preservative. In all specimens the mouthparts were noticeably eroded and it is possible that erosion had shortened the tips of the urogomphal prongs and the ungulae of the legs.

The larvae attain a length in excess of 20 mm., probably exceeding 25 mm. when fully distended; greatest breadth exceeding 3 mm. Prongs of urogomphi (fig. 16, *c*) relatively straight through most of length, the converging tips being distinctly farther apart than in *sexualis* (fig. 16, *d*). Nasale much as in *sexualis,* but lateral projections usually present. Subnasale worn in specimens at hand, but appears to have 4 or 5 short, forward-projecting denticles. Coxae of prothoracic legs each bear up to 40 spinelike setae on anterior surface.

The material examined is stored in the Canadian national collection.

LUDIUS SPRETUS (Mannerheim)

Corymbites spretus MANNERHEIM, Bull. Soc. Moscou, vol. 25, p. 285, 1852.
Corymbites (Selatosomus) spretus (Mannerheim), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 381, 1927.

According to Masaitis (1931) this species is widely distributed over Siberia, being particularly abundant in the central and western areas. Pospelova (1937) includes *spretus* among the predominant wireworms in the steppe and forest steppe regions of western Siberia. It is a well-known pest (Beĭ-Bienko, 1928; Masaitis, 1929, 1931; Pospelova, 1937) of root and grain crops, becoming most abundant in fields covered with *Agropyron repens.* Masaitis (1929) reports that pupation occurs during the latter half of July, at from 3 to 6 inches below the soil surface. The pupal period lasts 3 to 4 weeks.

Larvae of this species have not been available for examination in the present study. Knowledge of their morphology is limited to the description and figures given by Masaitis (1931). Since Masaitis' study was restricted to a comparison of the larvae of *spretus* and *Ludius latus* (Fabricius) it is not possible, at present, to give structural characters separating *spretus* and its closer allies, and primary reliance must still be upon geographical distribution.

The following is a summary of the most significant characters of the ninth abdominal segment, as described by Masaitis: Segment subquadrangular, only slightly narrowed posteriorly; dorsum convex, finely wrinkled, bearing 6 setae arranged as 3 transverse rows of 2

setae each; 1 to 3 tubercles on each lateral margin of dorsum, placed close together and located toward the posterior end of segment; urogomphal prongs of equal size, with sclerotized tubercles on the ventral side at the point where the prongs diverge.

LUDIUS MELANCHOLICUS (Fabricius)

Elater melancholicus FABRICIUS, Systema Entomologiae, Suppl., p. 130, 1798.
Diacanthus melancholicus (Fabricius), GERMAR, Zeitschr. fur die Ent., vol. 4, p. 80, 1843.
Ludius melancholicus (Fabricius), GEBLER, Bull. Soc. Moscou, vol. 20, p. 425, 1847.
Corymbites melancholicus (Fabricius), BOSE, Die Kafer Deutschlands von Valentin Gutfleisch, p. 362, 1859.
Selatosomus melancholicus (Fabricius), MOTSCHULSKY, *in* Schrenck's Reisen und Forschungen im Amur-Lande, vol. 2, p. 109, 1860.
Corymbites (*Selatosomus*) *melancholicus* (Fabricius), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 378, 1927.

Xambeu (1912, p. 142) described the larva of this European species under the name *Diacanthus melancholicus* Olivier. The larvae are said to be carnivorous and to inhabit the soil under well-sunken stones, or under the dung of large ruminants, at altitudes up to 1,800 meters. Pupation occurs in July, with the adults appearing in August.

Specimens were not available for examination in the present study and Xambeu's description is not adequate for the accurate identification of the species or for determination of its relationships.

The most important characters given by Xambeu may be summarized as follows: Length 25 mm.; breadth 2.5 to 3.0 mm. Nasale unidentate. Prothorax densely punctate; abdominal segments sparsely punctate, ornamented laterally with 2 groups of setae. Ninth abdominal segment with dorsal plate strongly punctate and bearing 3 "teeth" on each side. Caudal notch horseshoe-shaped. Urogomphi bifid, prongs darkened, arched, and converging; 1 tubercle at base of each prong.

* * *

LUDIUS AMPLICOLLIS (Germar)

Diacanthus amplicollis GERMAR, Zeitschr. für die Ent., vol. 4, p. 80, 1843.
Corymbites amplicollis (Germar), CANDEZE, Monographie des elatérides, vol. 4, p. 155, 1863.
Corymbites (*Selatosomus*) *amplicollis* (Germar), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 373, 1927.

The larva of this European species is described by Xambeu (1912, pp. 144-148), who reports it as abundant in mountains at 800 to 1,200

meters. The larva is stated to be carnivorous, especially on ants, and frequents the nests of *Formica coespitum* Linnaeus. Xambeu states that, in contrast to all other species of *Ludius, amplicollis* completes its life cycle in 1 year, the eggs hatching at the end of summer, the larvae that emerge pupating the following May.

Xambeu's description is inadequate both for the accurate identification of the species and for determining its relationships. Specimens were not available for examination in the present study.

The following is a summary of the most important larval characters given by Xambeu: Length 16 to 18 mm.; breadth 2 to 3 mm. Young larvae yellowish; older specimens reddish, venter yellowish. Nasale dark and tridentate. Eyes present. Prothorax finely punctured. First 8 abdominal segments punctate, each bearing a posterior transverse row of 6 or 7 reddish setae. Spiracles in anterior half of each segment. Ninth abdominal segment long, narrow, strongly punctate. Caudal notch large. Urogomphi bifid, outer prong long and arched. Anal opening linear.

THE LUDIUS SEMIVITTATUS GROUP

FIGURE 16, *b, e*

The material at hand is entirely inadequate for the establishment of group characters, only a single specimen labeled "*Ludius fusculus* Lec. (or *semivittatus* Say)" being available.

Brown (1936a, pp. 11-17) has shown that the adults of *semivittatus* (Say) and its allies have been much confused in collections. He erected the species *deceptor* Brown and *funereus* Brown for specimens that he believed Dr. Van Dyke and others had misidentified as *fusculus* (LeConte), the latter being excluded from the *semivittatus* group. In addition, *blanditus* Brown and *sexguttatus* Brown were created for species commonly confused with *semivittatus* (Say). Thus, it is impossible to state which species, as recognized by Brown, is represented by a specimen labeled "*Ludius fusculus* Lec. (or *semivittatus* Say)," but in all probability it is one of the western species included by Brown in his *semivittatus* group.

This larva reveals a close relationship to the *edwardsi* group. As with the *edwardsi* larvae, the most striking feature is the horny urogomphal prongs (fig. 16, *e*) shaped as grappling hooks. The two groups may be separated as follows: In *semivittatus*, the pleurites

of the first abdominal segment (*pl*, fig. 16, *b*) are virtually as long as the sternum, in *edwardsi* less than three-fourths as long; in *semivittatus*, there are 3 lateroepicranial setae, arranged as a dorsal pair and 1 unpaired ventral hair; in *edwardsi* there are 2 pairs..

On the basis of larval characters, this species might have been retained with the *edwardsi* group. The decision to place it in a separate group was based primarily on the fact that it differed in characters that were constant in the other species.

LUDIUS SEMIVITTATUS (Say) (?)

FIGURE 16, *b*, *e*

Elater semivittatus SAY, Journ. Acad. Nat. Sci. Philadelphia, vol. 3, p. 174, 1823.—LECONTE, Complete writings of Thomas Say, vol. 2, p. 113, 1859.
Ludius semivittatus (Say), BROWN, Canadian Ent., vol. 68, p. 13, 1936.

As stated above, this is the larva of *semivittatus* (Say) or of a closely allied western species. The single specimen upon which this study was made was collected at Walla Walla, Wash., but the range of the species cannot be stated with certainty. Nothing is known of the larval habits except that the available specimen was taken from an alfalfa field.

This larva strongly resembles that of *Ludius sexualis* Brown. Only the main differences from *sexualis* are described since the specimen is not in sufficiently good condition for an adequate detailed comparison.

Length about 15 mm. Nasale consisting of a large median tooth with a prominent lateral projection on each side near base; lateral denticles appear serrate anteriorly because subnasal sclerotization is closely joined with them. Subnasale consisting of transverse ridge, slightly convex ventrally, serrate, with 7 to 10 short, forward-projecting denticles (eroded condition of specimen prevents exact count). Epicranial plates with 3 lateroepicranial setae, arranged as 1 pair with an unpaired hair farther ventrad. Coxa of prothoracic leg with 40 spinelike setae on anterior surface. Pleurite of first abdominal segment (*pl*, fig. 16, *b*) nearly as long as sternum; on second and third segments, respectively, pleurites about three-fourths and one-half as long as sterna. Urogomphi (fig. 16, *e*) differing from *sexualis* as follows: inner prongs (*ipr*) somewhat stouter than outer prongs (*opr*), and with more pronounced tubercle (*tub*) on posterolateral aspect.

The specimen examined is deposited in the U. S. National Museum.

THE LUDIUS PROPOLA GROUP

FIGURES 13, *c*; 17

KEY TO SPECIES

1. Outer prongs of urogomphi (fig. 17, *d*, *e*) at least three times as long as inner prongs; Rocky Mountains and Pacific coast.............. ....**pudicus** Brown (p. 74)
   Outer prongs of urogomphi (fig. 17, *a*, *f*, *g*) not more than twice as long as inner prongs; east of Rocky Mountain region.............. 2
2. Inner prongs of urogomphi (*ipr*, fig. 17, *f*, *g*) twice as long as width at base; larva may exceed 16 mm. in length; eastern North America... ....**hieroglyphicus** (Say) (p. 73)
   Inner prongs of urogomphi (*ipr*, fig. 17, *a*) less than twice as long as wide; larva not exceeding 16 mm. in length; Atlantic coast to Rocky Mountains ....**propola propola** (LeConte) (p. 68)

Group characters are based on larvae of *propola* (LeConte), *pudicus* Brown, and *hieroglyphicus* (Say). All are North American species and believed to be forest inhabitants.

These larvae bear superficial resemblance to those of the *triundulatus* group, but are readily separated by the following characters: Outer urogomphal prong with sharp tip (fig. 17, *c-g*), antenna (fig. 17, *b*) with 1 "sensory" appendix, impressions shorter on abdominal mediotergites, and sternum undivided in first 5 abdominal segments.

Larvae of the *propola* group are bright yellow. Caudal notch large, subovate, U-shaped or approaching V-shaped. Urogomphi bifid, with outer prongs larger than inner prongs; tip of outer prongs sharp, inclining forward. Ninth abdominal segment without setae on central dorsal area; and with 3 prominent, blunt "teeth" on lateral margins of dorsum. Nasale unidentate, with 2 to 6 setae on each side of base, in sinuosities between nasale and paranasal lobes. Second joint of antenna bearing 1 "sensory" appendix. Eyes present. Basal joint of labial palpi with 1 small seta on ventral aspect. Gula short, but relatively wide. Frontoclypeal area bluntly rounded posteriorly. Mandible much as *aeripennis* type, with short, moderately deep dorsal groove. Presternum of prothorax divided into 3 sclerites. Episterna of mesothorax and metathorax without spinelike setae. Mediotergites of abdominal segments with prominent setae unpaired (at least not definitely paired), and transverse branch of impressions not exceeding four-fifths of the distance from longitudinal branch to middorsal suture. Sternum of 1 piece on first to eighth abdominal segments.

LUDIUS PROPOLA PROPOLA (LeConte)

FIGURES 13, *c*; 17, *a-c*

Corymbites propola LECONTE, Trans. Amer. Philos. Soc., vol. 10, p. 437, 1853.
Corymbites furcifer LECONTE, Trans. Amer. Philos. Soc., vol. 10, p. 438, 1853.
Ludius propola propola (LeConte), BROWN, Canadian Ent., vol. 68, p. 184, 1936.

The taxonomy of this species and its nearest relatives has been revised by Brown (1936d). The typical *propola* is regarded as an eastern species which ranges from Maine and Nova Scotia to the Rocky Mountains, where it is replaced by the subspecies *columbianus* Brown.

The larva of only the typical form is known. All specimens were found in litter under poplar or spruce or mixed stands of these two trees. Pupation occurs in late July, with the adults developing in early August. One pupa was found inside of a small decayed twig and another within a cell in leafmold.

The larva resembles the larger *hieroglyphicus* (Say), from which it differs by having shorter and stouter urogomphi and prongs (fig. 17, *a*, *c*).

Description of "mature" larva.—Length 16 mm., fully distended; greatest breadth 2.0 mm. on fourth to sixth abdominal segments. Body robust; with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum bright yellow (between "ochraceous buff" and "clay colour," Ridgway, 1912); head and urogomphi somewhat darker; venter paler. Dorsum slightly rugose, sparsely punctulate.

Head subquadrangular with slightly arcuate sides; flattened above and below.

Frontoclypeal region with posterior part extending backward almost to foramen magnum, usually bluntly rounded posteriorly. Two or three prominent anterior nasosulcal setae on each side of base of nasale. Nasale unidentate, terminating sharply when uneroded. Subnasale consisting of strongly sclerotized transverse ridge; serrate when uneroded, with 6 to 8 subequal, short, sharp, forward-projecting denticles. Paranasal lobes produced beyond nasale, each bearing 3 or 4 setae (1 or 2 small).

Epicranial plates sparsely and finely punctulate. Dorsal sulci wanting or practically so, but in usual region of each are 4 setae, subequally spaced, the most anterior seta being very long, others very small. Ventral sulci bearing row of 6 to 9 setae, usually 5 to 8 conspicuous. Two pairs of lateroepicranial setae (1 of each pair usually

short, sometimes lacking) and 2 unpaired setae farther dorsad, the more lateral of the unpaired setae is definitely more anterior than the paired hairs; 1 or 2 additional tiny setae sometimes present. Eye spot black, well defined, ovate or circular; surrounded by 3 or 4 prominent setae. Postgenal areas expanded mesad but always rather widely separated; glabrous.

Gula short; narrowed slightly by converging postoccipital sutures, but of good width; glabrous.

Antenna (fig. 17, *b*) with first joint weakly clavate, usually at least five-sixths as wide as long; without setae; 2 or 3 small pores. Second joint subcylindrical, as wide as long; one-half to three-fifths length of basal joint; 1 or 2 pores; a few small "sensory" pegs and setae borne distally; 1 large conical "sensory" appendix (*sap*) just ventrad to base of third joint. Terminal segment small, as long as second joint, but only one-quarter to one-third as wide; 4 or 5 setae on apex.

Mandibles of moderate length, robust; about five-sevenths as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with short, moderately deep dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts from two-thirds to three-fourths as wide across bases of stipites as at anterior ends of stipites. Cardines well separated. Stipes large, only two-thirds as wide posteriorly as anteriorly; proxistipes and dististipes not distinct; usually 5 to 8 prominent setae on antero-lateroventral aspect. Galea 2-jointed; basal joint subcylindrical, rather indefinite, shorter than terminal joint, without setae or pores; terminal joint narrower than basal segment, outer margin longer than inner margin, with 2 to 4 pores on lateroventral aspect. Maxillary palpi with all joints subcylindrical. First joint twice as wide as long; distally on mesoventral surface with group of 2 or 3 small pores and 2 setae, 1 or 2 pores near midventral aspect. Second joint wider than long; as long as first joint or slightly longer and at least two-thirds as wide; without setae; with 1 or 2 pores. Third joint wider than long; about one-half length of second joint; bearing 2 pores ventrally; distally with whorl of 4 or 5 fine setae; sometimes also 1 or 2 small "sensory" pegs distally. Fourth joint longer than wide; longer than third joint; one pore laterally and sometimes 1 minute seta near middorsal aspect. Postmentum with 1 long seta at each corner, 1 smaller seta short distance anterad

to each long anterior hair, usually 2 or 3 small hairs along each side; few minute pores laterally. First prementum with 1 large and 2 smaller setae just caudad to base of each palpus, forming transverse row of 6 hairs. Labial palpi with basal joint about one-half length of first prementum, about as long as wide, 1 seta ventrally, 1 or 2 pores; terminal joint nearly as long as basal joint and one-half as wide, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; usually slightly wider than long. Tergites minutely punctulate; anteriorly with from 10 to 14 setae (on each side of median dorsal suture) in transverse row, usually 8 to 12 prominent, remainder small or minute, none definitely paired, all well removed from middorsal suture; posteriorly with 6 to 10 setae arranged transversely in irregular row, about 5 to 8 prominent, none definitely paired; sometimes 1 or more fine setae approximately midway between transverse rows, usually laterad to center of sclerite. Episternum with 1 large and 2 or 3 small setae. Epimeron bearing 1 small seta. Presternal area consisting of 3 sclerites as follows: a small posterior median sclerite, anteriorly attenuate, with 2 fine short setae anteriorly; 2 large subtriangular lateral sclerites (usually joined anteriorly), striate on anterolateral aspect, with 1 stout seta laterad of center and a diagonal row of 3 or 4 minute "sensory" pegs or setae on anteromedial aspect. Eusternum small, membranous or weakly sclerotized; furcal pits each with 1 minute seta. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; transverse branch of impression reaching about one-fifth to one-third distance from longitudinal branch to middorsal suture; longitudinal branch of impression short. Anterior part of each mediotergite without setae except for a few minute hairs issuing from some of punctures. Posterior part of each mediotergite with from 5 to 9 unpaired setae in transverse row, about 5 to 7 prominent, remainder small or minute. Lateral part of mediotergite with 2 or 3 prominent setae, sometimes additional small or minute hairs. Anterior laterotergite subtriangular, one-half to two-thirds as large as subovate posterior laterotergite. Episternum bearing 1 or 2 fine setae but without spinelike setae. Eusternum with 2 conspicuous setae, sometimes additional minute setae. Mesothoracic spiracle small, usually slightly larger than spiracles in abdomen.

Legs subequal in length. Coxae of prothoracic legs with from 12 to 16 spinelike setae on anterior aspect, on mesothoracic and metathoracic legs with 16 to 20 such setae; 2 or 3 stout setae and a few

fine hairs scattered on posterior surface. Trochanter with 4 to 6 spinelike setae on medioanterior surface; 3 to 4 such setae and 1 fine seta scattered on posterior surface; 2, sometimes 3, well-developed setae on medial aspect. Femur usually with 6 to 9 spinelike setae on medioanterior surface; 2 or 3 spinelike setae and 1 or 2 slender setae on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 3 to 5 spinelike setae and 1 slender seta on medioanterior surface; 2 to 5 spinelike setae on posterior surface; usually 1 or 2 fine setae laterally. Ungula, when uneroded, about three-fifths as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites with scattered small punctures; transverse branch of impression slightly sinuate, on second to eighth segments reaching from one-half to slightly over two-thirds distance from longitudinal branch to middorsal suture, shorter on first segment; longitudinal branch of impression extending from two-thirds to five-sixths distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite without row of setae. Posteriorly on each mediotergite, transverse row of 5 to 8 prominent unpaired setae and usually 3 to 5 shorter setae placed between (and sometimes slightly caudad to) some of larger hairs. Usually 2 to 4 setae along margin of mediotergite, laterad to impression. Laterotergite I extending length of segment; with 4 or 5 setae. Spiracles small, subequal in all segments; spiracular sclerite small, subovate, in anterior half of segment, nearing middle of segment in posterior part of abdomen. Pleurite large, subovate, usually with 2 prominent setae, sometimes also 1 or 2 minute hairs. Sternum typically of 1 piece, subquadrate; with faint impressions near lateral aspects (only rarely are these impressions deepened or suturelike, separating off laterosternites on some of the more anterior segments); usually 6 to 8 prominent unpaired setae around margin of sclerite, sometimes also a few minute setae.

Ninth abdominal segment (fig. 17, *a*,), exclusive of urogomphi, about as long as eighth abdominal segment and three-fourths as wide; almost as long as wide; sides of anterior half subparallel, posterior half tapering caudally, making width at anterior margin of caudal notch about two-thirds greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; with a few small pits; 4 faint longitudinal impressions, 2 laterally and a short paramedian pair (in anterior part of plate) which converge posteriorly

but do not meet; without setae except at lateral margins, which are slightly raised and carinate, and bear 3 prominent blunt "teeth," each with a long bristle; transverse impression (*trim*) continues completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 10 to 16 unpaired setae on each side, some issuing from small sclerotized tubercles; anteriorly on lateral aspects with a few small punctures. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth of total length of segment (exclusive of urogomphi). Pleural area large, consisting of transversely striated membrane except at anterior ends where small ovate pleurite. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture, and posteriorly by tenth abdominal segment; each sclerite with from 6 to 9 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 17, *a*; fig. 17, *c*) separate, bifid; projecting caudad or dorsocaudad; inner prong usually about one-half size of outer prong. Inner prong (*ipr*) short, projected caudad and usually slightly dorsomediad, with sharp upturned tip; less than twice as long as wide; 2 large setae, 1 on caudolateral aspect, other ventrally at base of prong; usually a few minute hairs scattered on prong. Outer prong (*opr*) usually well developed; projecting caudodorsad, sometimes slightly laterad, terminating in sharp, horny point usually curving forward at tip; 2 large setae, 1 from anterolateral surface (usually in distal half of prong), other from lateral aspect of base of prong; several minute setae scattered over prong, the most noticeable usually on anteromesal surface near tip of prong. Undivided part of urogomphus with 1 to 3 setae on ventral aspect, usually 1 or 2 large.

Caudal notch (*cn*) large, U-shaped, sometimes with anterior margin slightly notched; longer than wide; usually only slightly narrowed posteriorly.

Tenth abdominal segment with whorl of 10 fine setae; sometimes additional minute setae in complete or partial whorl farther proximad; anal aperture linear and median.

Material used in study.—Examination was made of 15 specimens, including the larval exuviae of 2 specimens reared to maturity. Reared adults were identified by W. J. Brown, Ottawa. All specimens were collected in Saskatchewan at the following points: Saskatoon (4), Katepwa (1), Emma Lake (3), Round Lake (7). Unfortunately no whole larvae were collected at the same time and place as the specimens that were reared, but some were collected on different dates

from the identical spot at Saskatoon from which a reared specimen had previously been taken. Notes follow on reared adults and their associated exuviae.

1; Katepwa, Saskatchewan; Aug. 1, 1934; pupa and larval exuvium found together in pupal chamber; adult emerged by August 20; R. Glen. (C.N.C.)
1; Saskatoon, Saskatchewan; May 21, 1938; adult emerged July 24; R. Glen. (C.N.C.)
2; Arlington Heights, Mass.; (date collected not known); both specimens reared, No. 16393 emerging September 6, 1919, date of emergence of No. 16392 not known. (U.S N.M.)

LUDIUS HIEROGLYPHICUS (Say)

FIGURE 17, *f, g*

Elater hieroglyphicus SAY, Trans. Amer. Philos. Soc., vol. 6, p. 172, 1839.—LECONTE, Complete writings of Thomas Say, vol. 2, p. 607, 1859
Ludius bicinctus CANDEZE, Mem. Soc. Roy. Sci. Liege, vol. 17, p. 173, 1863.
Corymbites ctenicerus GEMMINGER and HAROLD, Catalogus Coleoptorum, vol. 5, p. 1577, 1869.
Ludius hieroglyphicus (Say), BROWN, Canadian Ent., vol. 68, p. 181, 1936.

This eastern species is recorded by Brown (1936d, p. 182) from the northeastern United States and from Quebec to Manitoba in Canada.

Blatchley (1910, p. 767) reports taking the adults from trees and shrubs about the margins of lakes and marshes. Larvae believed to be of this species were collected from the decomposing litter under spruce in New Brunswick and Nova Scotia. These were observed by R. F. Morris, Dominion Entomological Laboratory, Fredericton, New Brunswick, to attack the cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig), during rearing studies.

In *hieroglyphicus*, the prongs of the urogomphi (fig. 17, *f, g*) are relatively slender, the inner prongs being at least twice as long as their greatest width; the outer prongs are nearly twice as long as the inner prongs and much thicker. The size of mature larvae is not known, but it is certain that they would exceed 16 mm. (the maximum length of *propola* larvae) and probably would exceed 20 mm. Each gena usually bears only 3 lateroepicranial setae with an additional hair farther dorsad and another farther anterad; 1 exuvium had 2 pairs of lateroepicranial setae. Antenna with first segment two-thirds as wide as long and about twice as long as second segment. Coxae of prothoracic legs bearing up to 19 spinelike setae on each anterior surface; each coxa of mesothoracic and metathoracic legs with up to 24 spinelike setae. On mediotergites of second to eighth abdomi-

nal segments the transverse branches of impressions reach from two-thirds to four-fifths distance from longitudinal branches to middorsal suture.

Material used in study.—The only material available was the larval exuviae of two reared specimens and two whole larvae that by comparison were believed similar. The reared adults were identified originally by R. H. van Zwaluwenburg and checked by W. J. Brown, of Ottawa.

LUDIUS PUDICUS Brown

FIGURE 17, *d, e*

Ludius pudicus BROWN, Canadian Ent., vol. 68, p. 183, 1936.

This western species is known to inhabit British Columbia, southwestern Alberta, and the State of Washington.

Nothing is known of the larval habits since the only specimens available for study were reared from eggs laid in captivity.

The larva is well characterized by its very large, corniform outer prongs of urogomphi (*opr*, fig. 17, *d, e*), which are at least 3 times as long as the inner prongs. The largest larva examined was 17 mm. long, but mature specimens might be larger. Each gena bears only 3 lateroepicranial setae, with an additional seta farther dorsad and another farther anterad. First segment of antenna two-thirds as wide as long and about 3 times as long as second segment. Coxae of prothoracic legs bearing up to 25 spinelike setae on each anterior surface; coxae of mesothoracic and metathoracic legs with up to 35 spinelike setae. On each mediotergite of second to eighth abdominal segments the transverse branch of impression reaches about one-half of the distance from the longitudinal branch to the middorsal suture.

Urogomphi (fig. 17, *d, e*) well developed. Inner prong (*ipr*) short, projecting caudodorsad and slightly mediad with sharp, horny tip curving upward and slightly forward; bearing 2 large setae, 1 ventrolaterally near base, other ventrally at base; a few minute hairs on prong. Outer prong (*opr*) corniform, very large and strong; about as long as undivided part of urogomphus and at least 3 times as long as inner prong; projecting caudodorsad and slightly laterad, with sharp horny tip curving forward; 2 prominent setae, 1 on anterolateral aspect about halfway along prong, other (longer) laterally at base of prong; several minute setae scattered over prong, the most noticeable on the anteromedial aspect in distal half of prong. Undivided part of urogomphus with 1 prominent seta and 1 or 2 minute setae, all on ventral surface.

Caudal notch (*cn*) large, U-shaped or V-shaped.

Material used in study.—Two larvae were examined. Both had been reared from eggs obtained from adults collected at Walla Walla, Wash., by H. P. Lanchester and identified by M. C. Lane of Walla Walla, but the adults were not retained. The specimens are the property of the U. S. National Museum. One specimen (Truck Crop No. 2762) was identified as *L. pudicus* Brown, but the other (Truck Crop No. 2761) was identified as *Ludius propola columbianus* Brown. On the basis of larval characters this specimen is believed to be of the same species as larva No. 2762 and most likely to be *L. pudicus* and not *L. propola columbianus.* The evidence in support of this conclusion may be summarized as follows: (1) the two larvae are morphologically indistinguishable, except in characters known to vary between individuals; (2) specimen No. 2761 is larger than any specimen of the typical *propola* (which has been reared at the Saskatoon Laboratory), but according to Brown (1936d), adults of *propola columbianus* are not larger than those of *propola propola,* whereas adults of *pudicus* are larger; (3) the larvae in question are definitely distinct from the larva of *propola propola,* whereas the writer has not been able to find diagnostic subspecific characters for other larval Elateridae (e.g., in *Ludius aeripennis, Ludius cupreus,* and examples in other genera); and (4) a misidentification of the adult could easily occur, since Brown (1936d) writes in his description of *L. pudicus* (p. 183), "Frequently the subbasal markings are not extended on the second interval (of the elytra) and the specimens then resemble *propola columbianus* in color."

THE LUDIUS TRIUNDULATUS GROUP

FIGURES 13, *g;* 14, *d;* 18

KEY TO SPECIES

Outer prongs of urogomphi standing erect, forming an angle of approximately 90° with the undivided base of each urogomphus (fig. 18, *e*); Montana, Washington, British Columbia..**nebraskensis** (Bland) (?) (p. 81)

Outer prongs of urogomphi projecting caudodorsad, forming an angle of approximately 130° with the undivided base of each urogomphus (fig. 18, *f*); coast to coast in Canada...........**triundulatus** (Randall) (p. 76)

Knowledge of this group is based upon the larva of *triundulatus* (Randall) and upon a larva which is probably *nebraskensis* (Bland).

The closest relatives are found in the *propola* group from which distinction is secured through characters of the urogomphi (fig. 18,

e, f), antennae (fig. 18, *d*), sternum of the first 5 abdominal segments (fig. 18, *c*), and impressions on abdominal mediotergites (fig. 18, *b*).

Larvae of the *triundulatus* group are yellow or yellowish brown. Caudal notch large, U-shaped or V-shaped. Urogomphi bifid with subequal prongs; tip of outer prong smoothly rounded. Ninth abdominal segment without setae on central dorsal area, and with 3 "teeth" on lateral margins of dorsum. Nasale unidentate, with 2 setae on each side of base in sinuosities between nasale and paranasal lobes. Second joint of antenna bearing 2 "sensory" appendices. Basal joint of labial palpus without setae. Eyes present. Gula short, but relatively wide. Frontoclypeal area bluntly rounded posteriorly. Mandible with short, shallow, inconspicuous dorsal groove. Presternum of prothorax divided into 4 pieces. Episterna of mesothorax and metathorax without spinelike setae. Mediotergites of first to eighth abdominal segments with prominent setae unpaired (at least not definitely paired); on mediotergites of second to fifth abdominal segments the transverse branches of impressions usually reach to or almost to the middorsal line. Sterna of first to fifth abdominal segments divided by deep lateral sutures, usually closed in segments 6 to 8.

LUDIUS TRIUNDULATUS (Randall)

FIGURES 13, *g*; 14, *d*; 18, *a-d, f, g*

Elater triundulatus RANDALL, Boston Journ. Nat. Hist., vol. 2, p. 12, 1838.
Ludius triundulatus (Randall), BROWN, Canadian Ent., vol. 68, p. 106, 1936.

This species is known from the northeastern United States and from coast to coast in Canada.

The larvae have been found in abundance in damp litter and in very rotten wood under well-grown aspen poplar, but have also been collected from duff and decayed stumps under stands of willow, spruce, and pine. Larvae have been known to attack the cocoons of the European spruce sawfly,[7] *Gilpinia hercyniae* (Hartig), and it is concluded that they are chiefly predatory. In western Canada, transformation to the adult state appears to occur normally in July, pupation usually occurring in the first half of the month, but adults have emerged in August from material collected in eastern Canada. Under laboratory conditions the pupal period lasts about 1 week.

In structure, the larva is very similar to that of *nebraskensis* (Bland) (?), differing only in characters of the ninth abdominal segment (fig. 18, *f, g*).

[7] Information taken from labels accompanying larvae sent to the Saskatoon laboratory by R. E. Balch, Entomologist in Charge, Dominion Entomological Laboratory, Fredericton, N. B.

Description of "mature" larva.—Length 13 mm., fully distended; greatest breadth 1.4 mm. on fifth and sixth abdominal segments. Largest larva examined was 14 mm. long and 1.9 mm. wide. Body robust, with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum light brown or yellow brown (near "ochraceous tawny," Ridgway, 1912); head, prothorax, and urogomphi usually slightly darker; venter paler. Dorsum slightly rugose; with small shallow pits, rather inconspicuous.

Head subquadrangular with subparallel sides (very slightly arcuate); flattened above and below.

Frontoclypeal region with posterior part extending backward almost to foramen magnum, bluntly rounded posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (fig. 18, *a*), unidentate, terminating sharply when uneroded. Subnasale (fig. 18, *a*) consisting of strongly sclerotized transverse ridge, slightly convex anteriorly; serrate when uneroded, with approximately 15 subequal, short, sharp, forward-projecting denticles (fewer in smaller specimens). Paranasal lobes produced beyond nasale, each bearing 3 setae (1 small).

Epicranial plates finely punctulate. Dorsal sulci shallow, each with 4 setae subequally spaced, the most anterior seta very long, others small. Ventral sulci bearing row of 5 to 7 setae, usually 2 to 4 conspicuous. On each gena, usually 3 lateroepicranial setae, 2 large with 1 smaller seta between; sometimes with 1 very small seta ventrocephalad to the more ventral of the 2 large hairs; 1 well-developed seta slightly laterad of anterior half of dorsal sulcus. Eye spot black, well defined, ovate or circular; surrounded by 5 unpaired setae, 3 well developed, 2 small. Postgenal areas expanded mesad, but well separated; glabrous.

Gula short, moderately wide; glabrous.

Antenna (fig. 18, *d*) with first segment weakly clavate, at least three-fourths as wide as long; without setae; 3 to 5 small pores. Second segment subcylindrical, as wide as long; one-half length of basal joint; 1 or 2 pores; a few minute setae or pegs borne distally; 1 medium-sized conical "sensory" appendix (*sap*) just ventrad to base of third segment and 1 smaller appendix farther ventrolaterad; in a few specimens there were 2 smaller appendices, making a total of 3 appendices on 1 antenna, and in 2 specimens the small appendix was lacking on 1 antenna but present on the other. Terminal segment as long as second joint, but only one-quarter as wide; 3 or 4 setae on apex.

Mandibles of moderate length, robust; at least three-fourths as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half curving inward, pointed; outer surface convex with short, shallow, inconspicuous dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts about two-thirds as wide across bases of stipites as at anterior ends of stipites. Cardines separated by a distance equivalent to about one-half greatest width of single cardo. Stipites large, subrectangular, proxistipes and dististipes not distinct; usually 4 to 6 prominent setae on antero-lateroventral aspect. Galea 2-jointed; basal joint subcylindrical, not well defined, shorter than terminal joint, without setae or pores; terminal joint narrower than basal segment, outer margin longer than inner margin, 1 pore on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First joint wider than long; distally on mesoventral surface with group of 2 or 3 small pores and 1 or 2 setae. Second joint wider than long; about as long as first joint and almost as wide; without setae; 1 or 2 pores. Third joint almost as long as wide; about one-half length of second joint; 2 pores ventrally; distally with whorl of 4 small setae. Fourth joint slightly longer than wide; as long as or longer than third joint; without setae or pores. Postmentum with 1 long seta at each corner and 1 small or minute seta short distance anterad to each long anterior hair; 2 to 4 minute setae along each side. First prementum with 1 large and 1 small seta just caudad to base of each palpus, forming transverse row of 4 setae. Labial palpus with basal joint about one-half length of prementum, longer than wide, without setae, 2 pores; terminal joint narrow, but only slightly shorter than basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; about as wide as long. Tergites with minute punctures near middorsal suture, somewhat larger punctures laterally; anteriorly with 6 to 10 setae (on each side of median dorsal suture) in transverse row, usually 5 to 7 conspicuous, none definitely in pairs; posteriorly with 5 or 6 unpaired setae in transverse row, all well removed from middorsal suture; glabrous elsewhere. Episternum with 1 large seta and 3 or 4 small, fine hairs. Epimeron sometimes bearing 1 or 2 minute setae. Presternal area consisting of 4 sclerites as follows: A small posterior median sclerite, anteriorly attenuate, posteriorly rounded, bearing 2 minute hairs anteriorly; 2 large subtriangular lateral sclerites striate on anterolateral aspect, with 1 stout

seta laterad to center and a row of 4 or 5 minute setae on anteromedial aspect; and a very narrow, median, anterior piece. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites punctulate; transverse branches of impressions reaching about one-fourth to one-third distance from longitudinal branches to middorsal suture; longitudinal branches of impressions short, about one-half length of transverse branches. Anterior part of mediotergite without setae; posterior part with 4 or 5 conspicuous unpaired setae in transverse row, all well removed from median dorsal suture; lateral part with 2 large setae and sometimes 1 small seta, the most anterior hair being laterad to longitudinal branch of impression; minute setae sometimes observable in punctures. Anterior laterotergite subtriangular or subovate, one-half as large as subovate posterior laterotergite. Episternum without spinelike setae, 1 or 2 short, fine setae. Eusternum with 2 conspicuous setae, sometimes 2 to 4 minute setae. Mesothoracic spiracle slightly larger than spiracles in abdomen.

Legs subequal in length. Coxae of prothoracic legs with from 10 to 16 spinelike setae on each anterior aspect, on mesothoracic and metathoracic legs with 17 to 21 such setae, mostly in 1 row; 2 or 3 stout setae and a few fine hairs on posterior surface. Trochanter with 5 or 6 spinelike setae on medioanterior surface; 2 to 5 such setae and 1 fine seta scattered on posterior surface; 2 well-developed setae on medial aspect. Femur usually with 6 to 8 spinelike setae on medioanterior surface; 2 to 4 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 5 or 6 setae around distal margin; 2 to 4 spinelike setae and 1 slender seta on medioanterior surface; 1 to 3 spinelike setae on posterior surface. Ungula, when uneroded, about three-fifths as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (fig. 18, *b*) punctulate; transverse branches of impressions (*trim*) slightly sinuate, on second to fifth segments reaching to or nearly to median dorsal suture, on sixth and seventh segments usually slightly shorter, on eighth segment definitely not reaching dorsal suture, on first abdominal segment reaching only about one-half distance to dorsal suture (in a few specimens examined the transverse branches failed to reach the median dorsal suture in any segment); longitudinal branches of impressions (*loim*) extending obliquely backward at least two-thirds of distance

from transverse branch to posterior transverse row of setae and in some cases nearly the whole distance. Anterior part of mediotergite without row of setae. Posteriorly on each mediotergite, transverse row of 4 to 6 prominent unpaired setae and usually 1 to 3 short, fine setae placed between some of larger hairs. One prominent seta and sometimes also 1 small seta on margin of mediotergite laterad to impression. Laterotergite I extending length of segment; with 3 setae. Spiracles subequal; about in middle of segment just ventrad to most anterior seta on lateral aspect of mediotergite. Spiracular sclerite pale, subovate, wider than spiracle and 2 to 4 times as long. Pleurite (*pl*, fig. 18, *c*) large, subovate with 1 large and sometimes also 1 small seta near center. Sternum (*st*) subquadrate; in first 5 segments laterosternites (*lst*) separated off by well-defined sutures which are usually closed in sixth to eighth segments, sutures sometimes slightly open on sixth segment; usually about 6 unpaired setae around margin of sternum.

Ninth abdominal segment (fig. 18, *g*), exclusive of urogomphi, about as long as eighth abdominal segment and three-fourths as wide; nearly as long as wide; posterior half tapering caudally, making width at anterior margin of caudal notch from three-fifths to two-thirds greatest width of segment. Dorsum slightly convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; sparsely punctulate; 2 faint irregular impressions laterally; paramedian impressions inconspicuous and indefinite, sometimes meeting in a small, shallow, central, ovate depression; without setae except at lateral margins, which are raised and carinate, bearing 3 blunt "teeth," each with a long bristle; transverse impression (*trim*) continues completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 7 to 9 setae on each side, some issuing from small sclerotized tubercles; segment slightly expanded anteriorly on lateral aspects, usually with a few faint pits. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fifth of total length of segment (exclusive of urogomphi). Pleural area large, consisting of transversely striated membrane except for small ovate pleurite at anterior ends. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite usually with 3 or 4 prominent setae and a few small setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 18, *g*; fig. 18, *f*) separate, bifid, projecting dorsocaudad; prongs subequal. Inner prong (*ipr*) projected caudad,

slightly dorsad, with short, sharp, upturned, horny tip; small tubercle on lateral aspect, slightly over half distance toward tip of prong; 2 prominent setae, 1 from base of tubercle and 1 from midventral surface of prong; sometimes 1 minute seta on ventral aspect anterad to large seta. Outer prong (*opr*) projecting caudodorsad (at an angle of about 45° to 50° with the inner prong) sometimes slightly laterad, terminating in a smooth, round, horny tip; small tubercle on midventral aspect of base; 2 prominent setae, 1 from base of tubercle and 1 projecting upward from upper surface of prong about two-thirds distance from base; usually a few minute setae on inner surface of prong toward tip. Undivided part of urogomphus with 1 large seta ventrally just anterad to junction of prongs.

Caudal notch (*cn*) large, U-shaped, anterior margin sometimes slightly notched.

Tenth abdominal segment with whorl of 10 fine setae; anal aperture linear and median.

Material used in study.—Fifty-one examples were examined, including the last larval exuviae of seven reared specimens. The reared adults were identified by W. J. Brown of Ottawa. All the material, including the adults, is stored in the Canadian national collection. All specimens examined were directly associated with reared examples.

43; Cypress Hills, Saskatchewan; June 3, 1934; specimen 16407-81N4(a) reared to adult, emerging in July 1934; R. Glen.

4; Cypress Hills, Saskatchewan; July 3, 1932; all reared to adults; H. McMahon and H. McDonald.

2; Elkwater Lake, Alberta; June 8, 1935; specimen 16407-81N5(a) emerged July 22, 1935; R. Glen.

1; Cascapedia River, Quebec; reared adult emerging Aug. 26, 1935; M. L. Prebble.

1; Golden Lake, Ontario; July 7, 1939; adult emerged Aug. 26, 1939; A. P. Arnason.

LUDIUS NEBRASKENSIS (Bland) (?)

FIGURE 18, *e*

Corymbites nebraskensis BLAND, Proc. Ent. Soc. Philadelphia, vol. 1, p. 355, 1863.

Ludius nebraskensis (Bland), BROWN, Canadian Ent., vol. 68, p. 106, 1936.

Brown (1936b, pp. 106-107) records this species from Montana and British Columbia. On the basis of adult characters, this author finds that *nebraskensis* (Bland) has been confused in collections with *triundulatus* (Randall) and *tigrinus* (Fall). The larva that has been considered as *nebraskensis* in the present study was reared from eggs obtained from adults collected in Washington State and identified by

M. C. Lane, of Walla Walla, Wash., as *L. triundulatus* (Randall). On the basis of larval characters it appears to be a distinct species from the one that has been reared from Quebec, Ontario, Saskatchewan, and Alberta, the reared adults of which have been identified by W. J. Brown as *triundulatus* (Randall). In a personal communication Mr. Lane states, "I should probably have designated one of Brown's species. It is the western variety, either *L. nebraskensis* (Bland) or *L. tigrinus* (Fall)." The larva of *L. tigrinus* (Fall) is not known, but *tigrinus* is a California species and thus less likely to be collected in Washington. Therefore, this larva is believed to be *nebraskensis* (Bland).

Nothing is known of the habits of the larva. Structurally, it may be distinguished from the larva of *triundulatus* by the following characters of the ninth abdominal segment: Segment relatively broad posteriorly and urogomphi more widely separated than in *triundulatus;* outer prongs of urogomphi (fig. 18, *e*) projecting dorsad, at right angles to the inner prongs and almost at right angles to the undivided parts of urogomphi; caudad notch more nearly V-shaped than U-shaped; and sharper "teeth" on lateral margins of dorsal plate.

This larva measured 8 mm. in length and 1 mm. in width, at the age of 6½ months. Since the adults of *nebraskensis* are larger than those of *triundulatus* it is expected that mature larvae should exceed 13 mm. in length. This specimen died and dried out before being preserved and so it was not entirely adequate for a complete comparative study. The specimen is deposited in the U. S. National Museum.

THE LUDIUS FALLAX GROUP

Figures 8, *d;* 19, 20

KEY TO SPECIES

1. From Europe 2
   From North America 4
2. Dorsal plate of ninth abdominal segment with a transverse groove joining two longitudinal impressions [8] .... **purpureus** (Poda) (p. 93)
   Dorsal plate of ninth abdominal segment (fig. 20, *a*) without a transverse groove 3
3. Posterior part of frons bluntly pointed (fig. 19, *b*); usually 5 "sensory" appendices on second segment of antenna (fig. 19, *d*) .... **tessellatus** (Linnaeus) (p. 84)
   Posterior part of frons broadly rounded; usually 2 "sensory" appendices on second segment of antenna (fig. 19, *e*) .. **castaneus** (Linnaeus) (p. 89)
4. Eastern North America .... **medianus** (Germar) (p. 92)
   Western North America 5

[8] Information taken from Beling (1883, p. 264, "*haematodes* Fab.").

5. Six "sensory" appendices on second segment of antenna..............
.... *viduus* Brown (?) (p. 90)
Five "sensory" appendices on second segment of antenna..............
.... *bombycinus* (Germar) (p. 91)

Group characters are drawn from an examination of larval material of *tessellatus* (Linnaeus) and *castaneus* (Linnaeus) of Europe, and from *viduus* Brown, *bombycinus* (Germar), and *medianus* (Germar) of North America. On the strength of Beling's description (1883, pp. 262-265), the European *purpureus* (Poda) has been included in this group, but specimens could not be secured for study.

The larvae appear to inhabit soil, leaf litter, and decaying wood, and probably are chiefly predaceous. Blunck (1925) refers to the adults of *tessellatus, castaneus*, and *purpureus* as injuring buds and blossoms of fruit trees and the tender shoots of oak and pine, but there are no records of plant injury by the larvae.

On the basis of larval characters, the *fallax* group is not closely related to the other groups of *Ludius* that have been studied. Superficial resemblance is found in the larvae of the *propola* and *triundulatus* groups, but separation is readily achieved through color, nasale (fig. 19, *c*), the number of "sensory" appendices on the second segment of the antenna (fig. 19, *d, e*), and the urogomphi (fig. 20).

Larvae of the *tessellatus* group are brown to dark brown, sometimes with a superficial appearance of transverse bands of chestnut brown and paler color, but never prominently patterned. Caudal notch large, U-shaped. Urogomphi bifid, prongs subequal or inner prongs larger than outer prongs; tip of outer prong with very short, sharp point inclined inward. Ninth abdominal segment without setae on central dorsal area; and with 3 or 4 prominent, blunt "teeth" on lateral margins of dorsum. Nasale with tridentate tip, median denticle sharp and longer than lateral denticles which are truncate anteriorly; with 4 to 6 setae on each side of base of nasale in sinuosities between nasal and paranasal lobes. Second joint of antenna bearing from 2 to 6 "sensory" appendices. Basal joint of labial palpus without setae. Frontoclypeal area either bluntly pointed or broadly rounded posteriorly. Gula usually elongate and narrow, shorter in *castaneus*. Eyes present. Mandible with very short dorsal groove and with ventral margin of inner face of distal half continuing proximally to base of penicillus. Presternum of prothorax divided into 3 pieces. Episterna of mesothorax and metathorax without spinelike setae. Mediotergites of first to eighth abdominal segments with prominent setae unpaired, and transverse branches of impressions reaching as far as three-fourths of the distance from the longitudinal branches to the middorsal line. Sternum of 1 piece on first to eighth abdominal segments.

LUDIUS TESSELLATUS (Linnaeus) [9]

FIGURES 8, *d;* 19, *a, b, d, f, g;* 20, *a, b, e*

Elater tessellatum LINNAEUS, Systema naturae, ed. 10, vol. 1, p. 406, 1758.
Elater holosericeum OLIVIER, Entomologie, vol. 2, No. 31, p. 27, 1790.
Ludius tessellatus (Linnaeus), ESCHSCHOLTZ, *in* Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.
Prosternon holosericeum (Olivier), LATREILLE, Ann. Soc. Ent. France, vol. 3, p. 152, 1834.
Corymbites tessellatus (Linnaeus), GERMAR, Zeitschr. fur die Ent., vol. 4, p. 62, 1843.
Prosternon tessellatum (Linnaeus), DU BUYSSON, Faune Gallo-Rhénane, vol. 5, p. 84, 1894.
Prosternon tessellatum (Linnaeus), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 399, 1927.

This species is known from northern and central Europe. The larva has been described from Denmark by Schiodte (1870, p. 518) and Henriksen (1911, pp. 267-268) and from Germany by Beling (1883, pp. 272-273).

The larvae inhabit both soil and decaying wood. The specimens used in the present study were collected from a beech stump, forest moss, and an old grass plot, and under stones. Schiodte records the larvae from meadow soil and Beling found larvae and pupae under the bark of rotten stumps of pine (*Pinus silvestris* Linnaeus). Xambeu (1912-13) states that the larvae feed upon xylophagous insects. That they are chiefly predaceous is further indicated by the total absence of records of plant damage by larvae of this species. Pupation occurs from late July to early August. The adults develop in August but spend the winter in their pupal cells.

Ludius tessellatus may be distinguished from its nearest European relatives by the following characters: Dorsum dark brown; 3 to 6 "sensory" appendices on the second joint of antenna (fig. 19, *d*); frons bluntly pointed posteriorly and terminating before reaching foramen magnum (fig. 19, *b*); and urogomphal prongs subequal or inner prongs only slightly longer than outer prongs (fig. 20, *a, b, e*). It is very similar in structure to the American species *medianus* (Germar), from which separation is best secured on the basis of distribution.

Description of "mature" larva.—Length 14 mm.; greatest breadth 2.5 mm. on fourth and fifth abdominal segments. Largest larva ex-

[9] In certain parts of Europe the name *tessellatus* Linnaeus is still used in reference to larvae of *sjaelandicus* Muller, in spite of the fact that these are distinct species, the synonym of *sjaelandicus* Muller being *tessellatus* Fabricius, nec Linnaeus.

amined was 17 mm. long and 3.0 mm. wide. Body robust, with large membranes on lateral aspect of thorax and abdomen; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum dark brown, each segment paler posteriorly, giving larva a superficial appearance of transverse bands of auburn shade (Ridgway, 1912) on paler background. Venter pale yellow, darker on under side of head and terminal part of ninth abdominal segment. Dorsum slightly rugose; minutely punctate, punctures usually more abundant on anterior half of segments.

Head (fig. 19, *a*) subquadrangular with slightly arcuate sides; flattened above and below.

Frontoclypeal region (fig. 19, *b*) with posterior part extending backward almost to foramen magnum, but terminating definitely before reaching foramen; bluntly pointed posteriorly. Four to six prominent anterior nasosulcal setae (*nsa*) on each side of base of nasale. Nasale (*n*) well developed; tip tridentate, median denticle sharp (when uneroded) and longer than lateral denticles which are truncate anteriorly. Subnasale consisting of almost straight transverse ridge, finely serrate when uneroded. Paranasal lobes slightly produced beyond nasale, each bearing 4 setae (1 small).

Epicranial plates sparsely and finely punctulate. Dorsal sulci practically lacking, but with 4 setae in sulcal area; the most anterior seta very long, others small. Ventral sulci bearing row of about 7 setae, usually about 2 to 4 conspicuous. On each gena, usually 2 pairs of lateroepicranial setae (*lev, led*) with 1 unpaired seta nearer dorsal sulcus and 1 nearer setae surrounding eye. Eye spot (*e*) black, well defined, ovate or circular; surrounded by 4 unpaired setae. Postgenal areas expanded mesally, almost meeting anteriorly; glabrous.

Gula (*gu*, fig. 19, *f*) elongate, narrowed anteriorly; glabrous.

Antenna (*ant*, fig. 19, *a;* fig. 19, *d*) with first segment clavate, two-thirds as wide as long; without setae; 3 or 4 small pores. Second segment subcylindrical, almost as wide as long; three-fifths length of basal joint; 1 or 2 pores; a few small setae or pegs borne distally; usually 5 (varying from 3 to 6) conical "sensory" appendices (*sap*) just ventrad to base of third segment. Terminal segment small, more than half as long as second segment but only one-quarter as wide; 4 or 5 setae on apex.

Mandibles of moderate length, robust; two-thirds to three-fourths as wide at base as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending, pointed; outer surface convex with very short dorsal groove; inner

face slightly excavate with small median carina, ventral margin of inner face sharp, slightly convex ventrally and continued proximally to base of penicillus, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts only three-fifths to two-thirds as wide across bases of stipites as at anterior ends of stipites. Cardines well separated mesally. Stipites large, subrectangular, noticeably wider anteriorly; proxistipes and dististipes not distinct; usually 5 or 6 prominent setae on antero-lateroventral aspect. Galea with basal segment subcylindrical, shorter than terminal joint, without setae or pores; terminal segment narrower than basal segment, outer margin longer than inner margin, 6 or 7 pores on ventral aspect. Maxillary palpi with all segments subcylindrical. First segment wider than long; distally on mesoventral surface with group of several small pores and 2 setae. Second joint as long as wide; as long as first segment and almost as wide; without setae; with 2 pores. Third joint wider than long; about one-half length of second segment; 2 or 3 pores ventrally; distally with 1 small seta on mesoventral aspect and 1 on lateral aspect. Fourth segment longer than wide; slightly longer than third joint; without setae or pores. Postmentum with 1 long seta at each posterior corner, 1 or 2 setae at anterior corners and 1 to 3 setae along lateral margins. First prementum with 3 or 4 setae just caudad to base of each palpus, forming transverse row of 6 to 8 setae. Labial palpi with basal joint at least one-half as long as prementum, slightly longer than wide, without setae, with 3 to 6 pores; terminal joint more than one-half length and about one-half width of basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; wider than long. Tergites minutely punctulate; anteriorly with from 9 to 12 setae (on each side of median dorsal suture) in irregular transverse row, usually 6 to 9 conspicuous, others tiny, none definitely in pairs; posteriorly with 7 to 9 unpaired setae in transverse row; laterally with 1 or 2 setae between rows. Episternum with 2 or 3 large setae. Epimeron bearing 1 tiny seta. Presternal area consisting of 3 sclerites as follows: A small posterior median sclerite, anteriorly attenuate, with 2 tiny setae anteriorly; 2 large subtriangular lateral sclerites, usually joined anteriorly, striate on anterolateral aspect with 1 stout seta laterad to center and a row of 4 or 5 minute "sensory" structures on anteromedial aspect. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites punctulate, punctures larger and more numerous anteriorly; transverse branches of impressions reaching from one-fourth to one-third distance from longitudinal impressions to middorsal suture; longitudinal branches of impressions short. Anterior part of each mediotergite without setae except for a few minute hairs issuing from punctures; posterior part with transverse row of 6 to 9 unpaired setae; lateral part with 2 to 4 setae along lateral margin. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite, 1 seta ventrally. Episternum with 1 or 2 fine setae but without spinelike setae. Eusternum usually with 2 to 4 setae (only 2 conspicuous) in transverse row just anterior to coxae. Mesothoracic spiracle usually slightly larger than spiracles in abdomen.

Legs subequal in length, of good length. Coxa with up to 25 spinelike setae on anterior aspect, usually less on prothoracic legs; a few scattered fine setae on posterior surface. Trochanter with 6 or 7 spinelike setae on medioanterior surface; 3 to 5 such setae and a few fine setae on posterior surface; 2 well-developed setae on medial aspect. Femur as long as or longer than trochanter and about as thick; usually with 8 to 11 spinelike setae on medioanterior surface; 3 to 6 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 4 spinelike setae and 1 slender seta on medioanterior surface; 3 or 4 spinelike setae on posterior surface. Ungula, when uneroded, at least three-fourths as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; third to sixth segments widest; all segments wider than thick. Mediotergites (fig. 19, *g*) with small punctures, larger and more numerous in anterior half of segment; transverse branches of impressions (*trim*) slightly sinuate; length variable, on second to eighth segments reaching from one-half to three-fourths distance from longitudinal branch to middorsal suture (sometimes a faint impression runs farther mediad, almost to dorsal suture), on first abdominal segment reaching about one-half of distance to middorsal suture; longitudinal branches of impressions (*loim*) extending back to or almost to posterior transverse row of setae. Anterior part of each mediotergite without setae, except for a few minute hairs in some of punctures. Posterior part of each mediotergite with 5 to 9 conspicuous unpaired setae and a few smaller hairs, together forming an irregular transverse row. Two to four setae on margin of mediotergite laterad

to impression. Laterotergite I extending length of segment; with 3 setae. Spiracles slightly larger in first abdominal segment; in anterior half of segment, nearer to middle of sclerite in the more posterior segments. Spiracular sclerite small, subovate or subcircular. Pleurite large, subovate; with 2 or 3 setae (1 large). Sternum subquadrate; of 1 piece; 4 faint impressions, anterior pair meeting medially; bearing from 6 to 12 setae, mostly around margins of sclerite.

Ninth abdominal segment (fig. 20, *a, b*) exclusive of urogomphi, slightly longer than eighth abdominal segment and five-sixths as wide; almost as long as wide; sides of anterior half subparallel, posterior half tapering caudally, making width at anterior margin of caudal notch about three-fifths greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; punctulate, punctures small; 4 longitudinal impressions, 2 laterally (*lim*) from both sides of which short impressed lines extend, and a short paramedian pair (*pim*) which converge posteriorly but do not meet; without setae except at lateral margins which are raised and carinate, bearing 3 prominent blunt "teeth," each with a long seta; transverse impression (*trim*) continues completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 12 to 18 setae on each side, some issuing from small sclerotized tubercles; 10 to 15 conspicuous punctures anteriorly on lateral aspect of segment. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth to one-fifth of total length of segment, exclusive of urogomphi. Pleural area (*pl*) large, consisting of transversely striated membrane. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite usually with from 6 to 9 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 20, *a, b;* fig. 20, *e*) separate, bifid; projecting prongs subequal or inner prong slightly longer. Inner prong (*ipr*) large; projecting caudad and slightly dorsomediad, with sharp upturned tip; 2 long setae, 1 laterally arising from a strongly margined socket and 1 halfway along ventral aspect. Outer prong (*opr*) usually slightly shorter than inner prong, projecting dorsocaudad and slightly laterad, with short horny tip (often absent due to erosion) curving anteromesad; 2 large setae, 1 ventrally at base of prong and 1 arising from anterior face of prong; sometimes a few fine, short setae around distal half of prong. Undivided part of uro-

gomphus with 1 large seta ventrally, just anterad to base of inner prong.

Caudal notch (*cn*) moderately large, U-shaped; usually not quite as wide as long, slightly narrower posteriorly.

Tenth abdominal segment (*10*, fig. 20, *b*) with whorl of 10 fine setae; usually 2 or 3 smaller setae on anterior aspect; anal aperture linear and median.

Material used in study.—Twenty-five specimens were examined. These were collected from Germany (21), Finland (3), and Denmark (1). The larvae are believed to be reliably named but reared adults were not available for confirmation. The material studied is deposited in the Canadian national collection, the U. S. National Museum, and van Emden's collection.

LUDIUS CASTANEUS (Linnaeus)

FIGURES 19, *c, e;* 20, *c*

Elater castaneus LINNAEUS, Systema naturae, ed. 10, vol. 1, p. 405, 1758.
Ludius castaneus (Linnaeus), ESCHSCHOLTZ, *in* Thon, Entomologisches Archiv, vol. 2, p. 34, 1829.
Corymbites castaneus (Linnaeus), LATREILLE, Ann. Soc. Ent. France, vol. 3, p. 150, 1834.
Corymbites (Anostirus) castaneus (Linnaeus), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 364, 1927.

The larva of this European species has been described from Denmark by Schiodte (1870, p. 521) and Henriksen (1911, pp. 265-266) and referred to by Beling (1884, p. 205).

The larval habitat includes both soil and decaying wood. One of the specimens used in the present study was taken from a stump. Schiodte records the larvae as inhabiting forest meadows, and Henriksen states (translation): "mainly in sunny clay slopes, but also found in beech stumps." The species is not referred to in the economic literature. This suggests that the larvae are probably chiefly predaceous, as are those of the closely related *tessellatus* (Linnaeus).

In structure, the larva is very similar to that of *tessellatus* (Linneaus), but may be readily distinguished by the following characters: Only 2 "sensory" appendices on the second antennal segment (*sap*, fig. 19, *e*); frons broadly rounded posteriorly; only 3 lateroepicranial setae, arranged as a dorsal pair with an unpaired hair farther ventrad; gula shorter than in *tessellatus;* and ninth abdominal segment with a deep median crease (*cr*, fig. 20, *c*) just in front of the caudal notch. Henriksen (1911, p. 266) records larvae attaining a length of 21 mm.,

but the largest specimen available for use in the present study measured only 12.5 mm.

It is possible that *castaneus* belongs to a distinct but closely related "species group," since in the characters of frons, gula, and antennae it departs from the general pattern found in *tessellatus, viduus, bombycinus,* and *medianus.*

Material used in study.—Three examples were examined, including the last larval exuvium of a reared specimen the adult of which was made available to the writer. Neither of the two whole larvae was collected at the same time as the reared specimen, but all three were from Denmark. The larvae examined are deposited in the U. S. National Museum. Notes on the reared specimen follow:

1; Holte, Denmark; Sept. 1, 1895; A. Ditlevsen. (R.V.A.C.)

LUDIUS VIDUUS Brown (?)

Ludius viduus Brown, Canadian Ent., vol. 68, p. 103, 1936.

Brown (1936b, pp. 103-104) shows this species to be widely distributed over the southern part of British Columbia where it has been found together with *bombycinus* (Germar). The larva described below was collected under a stone on a hillside bearing conifers.

The larva of *viduus* differs from that of *tessellatus* (Linnaeus) in being of paler color, especially on first to sixth abdominal segments, in possessing more setae on thorax and abdomen and more spinelike setae on the legs, and in having the inner prongs of urogomphi twice as long as the outer prongs. It is much more closely related to *bombycinus* (Germar), from which it differs in antennal characters.

Length 17 mm.; greatest breadth 3.0 mm., on fourth and fifth abdominal segments. Only one specimen was available for examination and its relative maturity is unknown.

Dorsum transversely banded with chestnut brown and paler brown, anterior part of each segment darker; first to sixth abdominal segments palest.

Antenna with second segment slightly more than one-half as wide as long and bearing 6 conical "sensory" appendices just ventrad to base of third segment.

Each tergite of prothorax with an irregular anterior transverse row of 20 to 25 setae, a posterior transverse row of 10 to 14 setae, and 2 setae along lateral margin. Each mediotergite of mesothorax and metathorax with posterior transverse row of 12 or 13 setae and 6 to 8 setae near lateral margin. Each mediotergite on first to eighth abdominal segments with irregular posterior transverse row of 15 to

20 unpaired setae, and 5 to 9 setae near lateral margin. Laterotergite I bearing 4 to 7 setae. Pleurite with 3 to 5 setae.

Coxa with up to 30 spinelike setae on anterior aspect. Trochanter with 8 to 10 spinelike setae on medioanterior surface, 7 to 9 such setae on posterior surface. Femur with 12 or 13 spinelike setae on medioanterior surface, 6 or 7 spinelike setae on posterior aspect. Tibiotarsus with 6 to 8 spinelike setae on medioanterior surface and 5 to 8 such setae on posterior surface. Ungula, when uneroded, as long as tibiotarsus.

On ninth abdominal segment, distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-eighth of total length of segment, exclusive of urogomphi.

Urogomphi as figured for *bombycinus* (Germar) (fig. 20, *d, f*). Inner prong of urogomphus large, twice as long as outer prong; directed dorsocaudad, terminating in sharp, upturned point; with 2 prominent setae, 1 on lateral aspect, the other on midventral area. Outer prong short, robust; directed dorso-caudolaterad, with short, horny tip turned mediad; with 2 large setae, 1 on anterior aspect, the other laterally at base of prong; a few fine, short hairs around distal half of prong. Undivided part of urogomphus with 1 large seta ventrally, just anterad to base of inner prong.

Caudal notch large, U-shaped, slightly longer than wide.

Tenth abdominal segment with about 20 fine setae in irregular whorl.

Material used in study.—Only one specimen was used. Three larvae of this type were collected from under a stone, along with two adults of this species, but two of the larvae died and disintegrated too badly for use in the study. Since the relationships of this species, based upon adult characters, agree with the evidence deduced from this larva, it is believed that the larva is reliably named. The material was taken at Kamloops, British Columbia, and the adults were identified by W. J. Brown, of Ottawa. The larva is deposited in the Canadian national collection.

LUDIUS BOMBYCINUS (Germar)

FIGURE 20, *d, f*

Diacanthus bombycinus GERMAR, Zeitschr. fur die Ent., vol. 4, p. 70, 1843.
Ludius bombycinus (Germar), BROWN, Canadian Ent., vol. 68, p. 101, 1936.

This species is known from Oregon, Washington, British Columbia, and the mountainous southwest of Alberta. Nothing is known of

the larval habitat, the only specimens available being obtained from eggs laid in captivity.

The *bombycinus* larva is very closely allied to that of *viduus* Brown. In the very inadequate material available for study the only observed difference was in the antennae. On the second antennal segment, *bombycinus* bears 5 "sensory" appendices, whereas *viduus* has 6. Whether this difference is constant and whether there are other reliable separating characters cannot be determined until more material of these species is available. Urogomphi as in figure 20, *d, f*.

Material used in study.—Only larval exuviae were available for examination. The specimen was reared from eggs secured from adults collected at Walla Walla, Wash., by H. P. Lanchester and identified by M. C. Lane. The parent adults were not retained. The exuviae are deposited in the U. S. National Museum.

LUDIUS MEDIANUS (Germar)

Diacanthus medianus GERMAR, Zeitschr. fur die Ent., vol. 4, p. 71, 1843.
Corymbites rubidipennis LECONTE, Trans. Amer. Philos. Soc., vol. 10, p. 437, 1853.
Ludius medianus (Germar), BROWN, Canadian Ent., vol. 68, pp. 100-101, 1936.

This eastern species is recorded by Brown (1936b, p. 101) as occurring from central Manitoba to the Atlantic seaboard and as far south as Massachusetts. The only larvae known were collected from decomposing litter under spruce and were found to attack the cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig).

The larva of *medianus* so strongly resembles that of the European *tessellatus* (Linnaeus) that separation is best made on the basis of distribution. In *medianus* the inner prongs of the urogomphi are only slightly longer than the outer prongs. This character suffices to distinguish the larva from its closest known American allies, *viduus* and *bombycinus*, in both of which the inner prongs are approximately twice as long as the outer prongs. The second segment of the antenna bears 5 "sensory" appendices and the legs carry as many spinelike setae as on the larvae of *viduus*.

Material used in study.—Two examples were examined, one being the last larval exuvium of a reared specimen. These were not collected at the same time or in the same location, but both were taken under spruce in New Brunswick.

1; South Branch, Kent County, New Brunswick; June 17, 1941; R. F. Morris; reared to adult. (C.N.C.)

LUDIUS PURPUREUS (Poda)

Elater purpureus PODA, Insecta Musei Gracensis, p. 41, 1761.
Ludius haematodes (Fabricius), ESCHSCHOLTZ, *in* Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.
Corymbites haematodes (Fabricius), LATREILLE, Ann. Soc. Ent. France, vol. 3, p. 150, 1834.
Corymbites purpureus (Poda), SEIDLITZ, Fauna Baltica, ed. 2, p. 173, 1888.
Corymbites (Anostirus) purpureus (Poda), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 366, 1927.

The larva of this central European species has been described by Nördlinger (1880, p. 8) and in greater detail by Beling (1883, pp. 262-265), who also refers to it in his later work (1884, p. 203). Henriksen's description (1911, pp. 264-265) appears to have been based upon the writings of Beling and not upon a personal study of specimens. Larvae of this species were not available for examination in the present study and the notes that follow were adapted from the literature referred to above. The inclusion of this species in the *fallax* group is made on the basis of apparent similarity of habitat of and structure in the larva of *purpureus* and those of *tessellatus* (Linnaeus) and *castaneus* (Linnaeus), as revealed in the writings of Beling and Henriksen.

According to Beling (1883, p. 265) the larvae live under the moss covering the forest floor and in meadows near forests. Pupation occurs in July or early August.

The larva strongly resembles *tessellatus* (Linnaeus), being distinguished by the following characters of the ninth abdominal segment: Near the middle of the dorsal plate, a transverse impression or groove unites 2 well-separated longitudinal impressions; caudal notch bootjack-shaped, about as broad as long, only slightly narrowed posteriorly.

Length up to 19 mm., width up to 3.0 mm.; biconvex, but very flat, tape-shaped; noticeably well supplied with long setae; dorsum dirty yellow-brown shading to reddish brown, with a broad dark-brown transverse band across anterior part of each segment, giving larva a superficial banded appearance. Prothorax with fine sparse punctation; mediotergites of mesothorax and metathorax with somewhat stronger punctation, especially on anterior half; mediotergites of abdominal segments with relatively coarse, dense punctures.

* * *

LUDIUS AFFINIS (Paykull)

Elater affinis PAYKULL, Fauna Svecica, vol. 3, p. 12, 1800.
Ludius affinis (Paykull), ESCHSCHOLTZ, *in* Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.

Corymbites affinis (Paykull), GERMAR, Zeitschr. fur die Ent., vol. 4, p. 63, 1843.
Corymbites (*Haplotarsus*) *affinis* (Paykull), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 381, 1927.

The larva of this European species is described by Beling (1883, pp. 276-278; 1884, p. 204). It is a woodland species, living chiefly in the litter and soil of drier parts of forests and to a lesser degree in decaying stumps. Pupation occurs in the last half of July and in early August. No reference to this species was found in the economic literature.

Beling's description is inadequate, both for the accurate identification of the larva and for determining its relationships. Specimens were not available for use in the present study.

The most important characters given by Beling may be summarized as follows: Up to 20 mm. in length and 2.5 mm. in breadth. Much flattened, moderately covered with hairs, and finely punctulate. Dorsum brown or yellowish brown. One "sensory" appendix on second segment of antenna. Mandible with relatively small retinaculum. Ninth abdominal segment flattened, with 3 well-rounded teeth on each lateral margin of dorsum. Urogomphi short and thick, bifid; outer prongs slightly larger than inner prongs and projecting obliquely upward. Caudal notch large, bootjack-shaped, wider than long, slightly narrowed posteriorly.

THE LUDIUS ROTUNDICOLLIS GROUP

FIGURES 14, *h*, *j*; 21; 22, *a*, *b*, *c*, *e*

KEY TO SPECIES

1. From North America; dorsum not distinctly patterned.............. 2
   From Europe; dorsum with distinct pattern of bright brown spots on pale yellow background (fig. 22, *a*); urogomphal prongs subequal (fig. 22, *c*, *e*)...........................**cinctus** (Paykull) (p. 104)
2. Without definite impressions on mediotergites of mesothorax and metathorax; with conspicuous seta near center of each abdominal mediotergite (fig. 21, *e*); inner prongs of urogomphi small (*ipr*, fig. 21, *g*) 3
   Small, but definite impressions on mediotergites of mesothorax and metathorax; without conspicuous seta near center of each abdominal mediotergite; inner prongs of urogomphi moderately developed (*ipr*, fig. 21, *c*, *d*); eastern United States.................. ....**sulcicollis** (Say) (p. 102)

3\. Eastern United States; the most posterior of the blunt "teeth" (*to*, fig. 21, *f*) on lateral margins of dorsal plate of ninth abdominal segment more than one-half as long as broad.................. . ...**rotundicollis** (Say) ("eastern species") (p. 96)
Western United States; the most posterior of blunt "teeth" (*to*, fig. 21, *h*) on lateral margins of dorsal plate only one-half (or less) as long as broad........ .....**rotundicollis** (Say) ("western species") (p. 97)

On the basis of larval characters, three species have been included in this group, namely, *rotundicollis* (Say), *sulcicollis* (Say), and the European *cinctus* (Paykull). The larvae (figs. 21, *b*; 22, *a*) of these species are noticeably well supplied with setae and differ from all other *Ludius* larvae examined in having the proxistipes and dististipes clearly separated (fig. 22, *b*). All are wood inhabiting and appear to be chiefly predaceous; they are commonly found just under the bark of decaying stumps and logs or of living trees, frequently in the galleries of wood-boring beetles.

The species are quite distinct and easily recognized and it might be that two, or even three, closely related groups are represented by the species that have been brought together here. However, it is believed preferable to retain them in one group until larval material of other related species is available for study. On the basis of adult characters, Van Dyke (1932, p. 428) groups the following North American species: *rotundicollis* (Say), *sulcicollis* (Say), *rupestris* (Germar), and *nunenmacheri* Van Dyke. Larvae of the last two species were not available for examination.

The larva of the European *Ludius bipustulatus* (Linnaeus) resembles the *rotundicollis* group in color, general setal characters, nasale, and in several other respects; but it differs in urogomphal prongs, sculpture of abdominal segments, type of sternum in abdominal segments, pleurite of ninth abdominal segment, mandibles, and maxillary stipites.

Larvae of the *rotundicollis* group vary in color from bright brown to very dark brown, sometimes with the dorsum distinctly patterned (fig. 22, *a*), venter always pale. Caudal notch large, U-shaped. Urogomphi bifid; prongs subequal or outer prongs larger than inner prongs; tip of inner prong sharp, upturned; tip of outer prong bluntly rounded. Ninth abdominal segment (figs. 21, *g*; 22 *c*) with moderately large pits on dorsum; usually without setae (rarely with 2 small setae) on central dorsal area; 2 to 4 blunt "teeth" on lateral margins of dorsum; distance from pleural area to caudal notch approximates one-tenth to one-eighth total length of segment; and with large pleurite (*pl*, fig. 21, *h*) anteriorly on each side. Nasale uni-

dentate. Frontoclypeal area bluntly rounded posteriorly. Second joint of antenna bearing 1 "sensory" appendix. Without setae on basal joint of labial palpus. Eyes present. Gula elongate and narrow. Mandible with relatively small retinaculum set in slight depression. Presternum of prothorax divided into 3 pieces. Episterna of mesothorax and metathorax without spinelike setae. Mediotergites of first to eighth abdominal segments with prominent setae unpaired (sometimes 2 most medial setae in semipaired arrangement), and transverse branches of impressions rarely exceeding one-half the distance from the longitudinal branches to the middorsal suture. On first to seventh abdominal segments sternum usually divided by lateral sutures into 3 pieces, pieces usually not completely separated. Anal aperture somewhat T-shaped.

LUDIUS ROTUNDICOLLIS (Say)

FIGURES 14, *j*; 21, *a*, *b*, *e-h*

Elater rotundicollis SAY, Ann. Lyceum Nat. Hist. New York, p. 259, 1825.
Corymbites rotundicollis (Say), LECONTE, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 440, 1853.
Ludius rotundicollis (Say), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 427, 1932.

According to Van Dyke (1932, pp. 404, 427-428) this species occurs in both the "Atlantic States and Pacific States," the more typical *rotundicollis* being in the East and the subspecies *nigricans* (Fall) and *diversicolor* (Eschscholtz) in the West. In the present study, larvae identified as *rotundicollis* (Say) have been obtained from the extreme eastern and the extreme western parts of the United States. The specimens from the two regions are very similar, but sufficiently different in structure to suggest specific distinction.

"Eastern species."—Larvae have been examined from Pennsylvania, Maryland, and New York State. The collectors' notes reveal that some specimens were taken from under bark on the trunk of an elm tree and others were observed attacking spiders in silken cocoons. Knull (1932, p. 43) reports the larvae as predaceous upon the larvae of cerambycids inhabiting the outer bark of numerous living deciduous trees. There are no records on the time of pupation, but Blatchley (1910, p. 768) observed the adults to hibernate beneath logs on sandy hillsides.

The larva of the "eastern species" may be distinguished from that of the "western species" by the following characters: Slightly paler in color, fewer setae, somewhat weaker punctation, a much more prominent posterior "tooth" (*to*, fig. 21, *f*) on the lateral margins

of the dorsal plate of the ninth abdominal segment, and without punctures in the region between the caudal notch and the pleural area of the ninth abdominal segment.

The largest larva examined was 14 mm. long and 2.5 mm. broad, but undoubtedly it was immature. Dorsum dark brown, eighth abdominal segment not darker than preceding segments. Each mediotergite on second to eighth abdominal segments with a posterior transverse row of 5 to 7 setae (8 to 15 setae in similar location in "western species").

Urogomphi (fig. 21, *f*) resemble those of "western species," but inner prongs relatively larger; outer prongs usually narrower at tips; and somewhat greater angle between prongs of each urogomphus.

"Western species."—Van Dyke (1932, p. 428) states that the subspecies *nigricans* (Fall) ranges throughout western Washington and Oregon and south along the high Sierra Nevada whereas the other western subspecies, *diversicolor* (Eschscholtz), is a lowland form that breeds in the rotting parts of old living oaks. Larvae used in the present study were taken from bull pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga mucronata*) in Oregon and California.

This larva (fig. 21, *b*) is readily identified by its very dark brown color, great abundance of setae, and the characteristic urogomphi (*ur*, fig. 21, *g*, *h*).

Description of "mature" larva of "western species."—Length 22 mm.; greatest breadth 3.5 mm. on fourth abdominal segment. A fully distended larva measured 24 mm. Body robust; convex dorsally, flatter ventrally; abundantly provided with setae; with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum dark brown, sometimes approaching black brown; head, prothorax, and eighth and ninth abdominal segments usually very dark; on abdominal segments pigmentation is stronger posterior to imaginary line joining transverse branches of impressions on mediotergites; venter pale yellow to creamy white, darker on ventral surface of head and terminal part of ninth abdominal segment. Dorsum slightly rugose, moderately to densely punctate, punctures small except on ninth abdominal segment.

Head (fig. 21, *a*) subquadrangular with slightly arcuate sides; not as thick at base as long; flattened above and below.

Frontoclypeal region extending backward to or almost to foramen magnum, bluntly rounded posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale unidentate, terminating sharply when uneroded. Subnasale consisting of transverse

ridge; serrate when uneroded, with at least 5 or 6 subequal, short, sharp, forward-projecting denticles. Paranasal lobes produced beyond nasale, each bearing 3 setae (1 small).

Epicranial plates punctulate. Dorsal sulci (*ds*) shallow and inconspicuous; each bearing 5 setae, subequally spaced, the most anterior hair being very long, the next seta small and the 3 most posterior setae very small. Usually 1 to 3 prominent setae anterad to dorsal sulci. Ventral sulci bearing row of 7 to 9 setae, usually about 6 or 7 conspicuous. Two pairs of long lateroepicranial setae (*led, lev,* fig. 21, *a*); also 1 seta farther dorsad and 1 or 2 unpaired setae farther anterad or anterodorsad (in region between paired setae and setae surrounding eye spot); sometimes additional minute setae scattered over surface. Eye spot (*e*) black, well defined, ovate or circular; surrounded by 5 or 6 unpaired setae. Postgenal areas slightly expanded mesad; glabrous.

Gula elongate, narrow; glabrous.

Antenna with first segment clavate, about two-thirds as wide as long; without setae; 3 to 5 small pores. Second segment subcylindrical, two-thirds as wide as long; three-fifths length of basal joint; 1 or 2 pores; a few small setae distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third segment. Terminal segment small, three-fifths as long as second segment and one-third as wide; a few setae on apex, 1 usually larger than others.

Mandible of moderate length, robust; about two-thirds as wide at base as long; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with moderately deep dorsal groove; inner face slightly excavate with longitudinal carina; ventral margin of inner face sharp and slightly convex ventrally, extending backward past retinaculum to near mesal aspect of base of mandible; dorsal margin of inner face sharp and strongly convex dorsally, extending backward to posterior limit of retinaculum. Retinaculum small for size of mandible, base somewhat recessed between elongate margins of inner face of anterior part of mandible.

Ventral mouthparts only two-thirds as wide across bases of stipites as at anterior ends of stipites. Cardines slightly separated. Stipes large, wider anteriorly, inner margin straight, outer margin slightly convex; proxistipes and dististipes distinct (as in *cinctus,* fig. 22, *b*); usually 4 to 6 prominent setae on antero-lateroventral aspect, with 1 or 2 small setae farther caudad. Galea with basal joint subcylindrical, shorter than terminal joint, without setae or pores; terminal segment narrower than basal segment, outer margin longer than inner

margin, with 4 or 5 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment wider than long; 5 or 6 small pores and 2 setae on ventral surface. Second segment as long as wide; as long as first segment and almost as wide; without setae; 2 or 3 pores. Third segment wider than long; about one-half length of second segment; 4 or 5 pores ventrally; distally with 1 or 2 small setae on mesoventral aspect and 1 seta on lateral aspect. Fourth segment longer than wide; longer than third segment; 1 small seta proximally on dorsal aspect; without pores. Postmentum elongate, almost twice as wide anteriorly as posteriorly; 1 long seta at each posterior corner, 2 long setae near each anterior corner; 1 or more setae along each side; few minute pores. First prementum with 2 (sometimes more) prominent setae just caudad to base of each palpus, forming transverse row of at least 4 setae. Labial palpi with basal joint cylindrical or slightly clavate, more than one-half length of prementum, longer than wide, without setae, 2 to 4 pores; terminal segment more than one-half length and about one-half width of basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites minutely punctulate; with from 30 to 45 setae (on each side of median dorsal suture) arranged as follows: anteriorly with 15 to 20 setae in a confused transverse row (most abundant laterally), posteriorly with 6 to 10 setae in an irregular transverse row, and 10 to 15 setae scattered between these rows mostly near the lateral margin. Episternum with 3 large setae. Epimeron bearing 1 small seta. Presternal area consisting of 3 sclerites as follows: a small posterior median sclerite, anteriorly attenuate, with 2 small setae anteriorly; 2 large, subtriangular lateral sclerites (sometimes joined anteriorly), striate on anterolateral aspect, with 1 stout seta laterad to center and a diagonal row of 4 or 5 minute setae on anteromedial aspect. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each at least twice as wide as long. Mediotergites rugulose; punctulate ; transverse branch of impression indefinite, consisting of a few disconnected punctures; longitudinal branch wanting. Each mediotergite bearing about 20 setae, usually arranged as follows: posterior transverse row of 6 to 10 setae, 8 to 10 setae along lateral margin, 2 or 3 slightly farther mesad and 1 long seta near center of sclerite. Posterior laterotergite large, subovate or subtriangular, bearing 1 large seta near dorsal margin. Anterior

laterotergite subtriangular or subovate, at least one-half as large as posterior laterotergite. Mesothoracic spiracle set in strongly margined circular orifice; much larger than abdominal spiracles. Episternum bearing 4 or 5 fine setae, but without spinelike setae. Eusternum with 6 fine setae (only 2 conspicuous) in transverse row.

Legs subequal in length. Coxae of prothoracic legs with up to 8 spinelike setae and several fine setae on anterior aspect, on mesothoracic and metathoracic legs with up to 14 spinelike setae and 5 to 8 fine setae, spinelike setae mostly in 1 row; a few fine setae scattered on posterior surface. Trochanter with 5 or 6 spinelike setae on medioanterior surface; 1 to 4 such setae and 2 or 3 fine setae scattered on posterior surface; 2 well-developed setae on medial aspect. Femur slightly longer and about as wide as trochanter; usually with 7 to 10 spinelike setae on medioanterior surface; 3 or 4 spinelike setae and 1 or 2 slender setae on posterior surface; 1 long seta on medial aspect; a few fine setae on lateral surface. Tibiotarsus with 4 fine setae around distal margin; 3 or 4 spinelike setae and 1 slender seta on medioanterior surface; 1 to 3 spinelike setae on posterior surface. Ungula, when uneroded, about two-thirds as long as tibiotarsus; base well expanded mesally with relatively long medial sclerite bearing 2 fine setae.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (fig. 21, *e*) with scattered small punctures, sometimes more abundant anteriorly; transverse branch of impression (*trim*) dark, slightly sinuate, with 6 to 9 minute punctures subequally spaced, on second to eighth segments reaching from one-third to one-half distance from longitudinal branch to middorsal suture, shorter on first segment and slightly longer on seventh and eighth segments; longitudinal branch of impression (*loim*) extending less than one-half distance from transverse branch to posterior transverse row of setae. Each mediotergite bears from 15 to 25 setae, usually arranged as follows: posterior transverse row of 8 to 15 unpaired setae, lateral group of 6 to 10 setae, and 1 seta toward center of sclerite; a few exceedingly minute setae sometimes observable on anterior part of sclerite. Laterotergite I extending almost whole length of segment; with 6 to 12 setae, mostly on dorsal and posterior aspects. Pleurite large, subovate, pale, usually with 6 to 12 long setae; size of sclerite and number of setae decrease from first to eighth segment. Sternum divided into 3 parts on first to seventh segments, inclusive, forming 2 laterosternites and 1 larger mediosternite; laterosternites each with from 4 to 6 setae,

mostly along lateral margin; mediosternite bearing from 4 to 8 setae and 2 very faint impressions meeting medially; sternum undivided on eighth segment.

Ninth abdominal segment (fig. 21, *g, h*), exclusive of urogomphi, about as long as eighth abdominal segment and at least three-fourths as wide; five-sixths to seven-eighths as long as wide; widest anteriorly; width at anterior margin of caudal notch about three-fourths to five-sixths greatest width of segment. Dorsum convex, sloping downward from front to back. Dorsal plate (*dpla*) irregularly wrinkled; densely punctate, punctures moderately large and deep; a pair of paramedian impressions (*pim*) converge posteriorly but do not meet; lateral impressions usually obliterated by submarginal depression; usually without setae (rarely with 2 small setae anteriorly) except at lateral margins, which are strongly raised and carinate, bearing 2 or 3 blunt "teeth" (*to*), only the most posterior being prominent; transverse impression (*trim*) dark and strong, continuing completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; densely punctured throughout with a few larger pits anteriorly on lateral aspects; usually with from 15 to 25 setae on each side, sometimes more. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-eighth of total length of segment (exclusive of urogomphi). Pleural area (*pl*) large, consisting of transversely striated membrane except at each anterior end, where there is a large pleurite which is posteriorly attenuate and bears 1 to 3 setae. Sternum of 2 sclerites, separated anteriorly by median longitudinal suture and posteriorly by tenth abdominal segment; each sclerite with about 10 setae, mostly in irregular row around tenth abdominal segment.

Urogomphi (*ur*, fig. 21, *g, h*) large, separate, bifid near tip, punctulate; prongs short, outer prong larger. Inner prong (*ipr*) small, fleshy with horny tip; arising from medial or medioventral margin of distal one-third of urogomphus; projecting caudad with upturned tip (sometimes eroded); without setae or tubercles. Outer prong (*opr*) short, robust, three times as wide as inner prong and longer; projecting dorsocaudad, terminating in blunt round tip (sometimes very broad at tip); without setae or tubercles. Undivided part of urogomphus usually with linear depression on ventral aspect at point of separation of prongs; 1 large seta on lateral aspect arising from deep cup with raised anterior margin; 4 to 6 setae ventrally, usually arranged as follows: 1 or 2 setae in depression between bases of prongs, 1 or 2 setae mesad to this depression and anterad to base

of inner prong, 2 or 3 setae laterad to depression and anterad to base of outer prong.

Caudal notch (*cn*) large, U-shaped; as long as wide or longer than wide; usually not narrowed posteriorly.

Tenth abdominal segment (*10*) with 20 or more setae in irregular whorl around distal end; anal aperture somewhat T-shaped with transverse portion to the rear.

Material used in study.—"Eastern species": Eight examples of this species were examined, including two larval exuviae that were believed to be associated with reared adults, but the adults were not available. These larval skins were from specimens collected at Mont Alto, Pa., January 25, 1931, J. N. Knull; apparently identified by Knull; (Pennsylvania Agricultural Experiment Station collection). The whole larvae examined were from Pennsylvania (4), New York (1), and Maryland (1) and are deposited in the U. S. National Museum.

"Western species": Seven examples, including one larval exuvium of a reared specimen, were studied. Unfortunately, the reared adult could not be found. This specimen was from Colony Mills, Sequoia Park, Calif., July 15, 1918; adult found in bottom of rearing cage September 29, 1919; F. C. C. (U.S.N.M. Hopk. U.S. 10652b). The whole larvae examined were from Oregon (3) and California (3) and are deposited in the U. S. National Museum.

LUDIUS SULCICOLLIS (Say)

FIGURE 21, *c, d*

Elater sulcicollis SAY, Trans. Amer. Philos. Soc., vol. 6, p. 168, 1836.
Corymbites sulcicollis (Say), LECONTE, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 441, 1853.
Ludius sulcicollis (Say), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 400, 1932.

Van Dyke (1932, p. 400) indicates that this species is distributed throughout the Atlantic States, and Leng (1920, p. 169) records it as far inland as Indiana.

The larvae are reported by Knull (1930, p. 83; 1932, p. 43) to inhabit decaying wood of sour gum (*Nyssa sylvatica*) and pitch pine (*Pinus rigida*) and hibernating adults have been taken by Blatchley (1910, p. 768) from under the loose bark of an ash snag. Knull (1932, p. 43) found an adult in its pupal cell on August 16, which suggests that the time and period of pupation are similar to those of most species of *Ludius*.

This larva is readily distinguishable from *rotundicollis* (Say) by its much paler color, relatively larger inner prongs on urogomphi (*ipr*, fig. 21, *c, d*), the presence of small but definite impressions on mediotergites of mesothorax and metathorax, and the absence of a seta near the center of each mediotergite of first to eighth abdominal segments. *Sulcicollis* resembles more closely the "eastern species" of *rotundicollis* than the "western species"; the similarity is most pronounced in the setation, the "western" *rotundicollis* bearing many more setae.

Length 15 mm.; greatest breadth 2.75 mm. A fully distended larva measured 21 mm. Dorsum chestnut brown, eighth and ninth abdominal segments darkest; on mediotergites of abdominal segments the pigmentation is slightly deeper in the regions lying within the angles of the impressions. Dorsum slightly rugose, moderately to densely punctate, punctures small, except on ninth abdominal segment.

Epicranial plates with 2 pairs of large lateroepicranial setae and 1 large seta farther dorsad, but without setae between the region of the paired hairs and the setae surrounding the eye; setae anterad to dorsal sulcal setae are either minute or wanting.

Tergites of prothorax each with from 18 to 30 setae; each mediotergite of mesothorax and metathorax bears 13 to 20 setae; and each mediotergite of abdominal segments carries 9 to 16 setae. Sternum of first to seventh abdominal segments divided as in *rotundicollis*, but bearing only about 7 to 10 setae.

Coxa of prothoracic legs with up to 12 spinelike setae on anterior surface, mesothoracic and metathoracic legs with up to 20 spinelike setae.

On ninth abdominal segment, region between pleurite and caudal notch without punctures and approximating one-tenth to one-eighth total length of segment, exclusive of urogomphi.

Urogomphi (fig. 21, *c, d*) large, separate, bifid, punctulate. Inner prong (*ipr*) small, about one-half size of outer prong, corniform, projecting mesocaudad with sharp, upturned tip; bearing 2 long setae, 1 ventrally at base of prong, the other at junction with outer prong. Outer prong (*opr*) large, fleshy, projecting dorsocaudad, sometimes slightly laterad, terminating bluntly rounded; with 1 large seta on anterolateral aspect near base of prong. Undivided part of urogomphus with 2 large setae ventrally just anterad to base of outer prong.

Caudal notch (*cn*) large, U-shaped, usually broader than long; usually not narrowed posteriorly.

Material used in study.—Six specimens were examined, including one larval exuvium. Though reared adults were not available for confirmation of the identity of the material studied, it is believed to be reliably named. The larval skin examined is from the Pennsylvania Agricultural Experiment Station collection and is labeled "*Ludius sulcicollis* Say, Cold Springs, Pa., VIII-16, J. N. Knull." In his "Notes on Coleoptera—No. 3," Prof. Knull (1932, p. 43) states, "LUDIUS SULCICOLLIS Say. An adult was found in its pupal cell in a decayed pitch pine (*Pinus rigida* Miller) snag at Cold Springs, Adams County, August 16." It is very likely that the larval exuvium examined was taken with its adult from the pupal cell referred to in this statement. Three whole larvae in the U. S. National Museum labeled "*Ludius sulcicollis* (?) Say, Hummelstown, Pa., V-20-'29, J. N. Knull, *Nyssa sylvatica*" are thought to be associated with the material of this species that was reared by Prof. Knull and reported by him (1930, p. 83) as follows, "LUDIUS SULCICOLLIS Say. Adults were reared from dead sour gum (*Nyssa sylvatica*) wood infested with *Leptura emarginata* Fab. and *Charisalia americana* Hald. collected at Hummelstown, Pennsylvania." The other larvae examined were from Pennsylvania (1) and Illinois (1).

LUDIUS CINCTUS (Paykull)

FIGURES 14, *h*; 22, *a-c*, *e*

Elater cinctus PAYKULL, Fauna Svecica, vol. 3, p. 10, 1800.

Hypoganus cinctus (Paykull), KIESENWETTER, Naturgeschichte der Insecten Deutschlands Coleoptera, 1857-1863, vol. 4, p. 299, 1858.

Corymbites cinctus (Paykull), BOSE, Die Käfer Deutschlands von Valentin Gutfleisch, p. 363, 1859.

Hypoganus cinctus (Paykull), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 402, 1927.

The larva of this European species has been described by Schiodte (1870, p. 519), Rupertsberger (1870, pp. 835-836), and Henriksen (1911, pp. 263-264) and is referred to by Beling (1884, p. 204).

The larval habitat is in decaying stumps and logs, particularly of oak and beech. Specimens are commonly found just under the bark and have been taken from the galleries of *Anobium*. Henriksen (1911, p. 264) states that pupation occurs in August and the imago develops in September, spending the winter in its pupal chamber.

The larva of *cinctus* is readily identified by its prominent color pattern (fig. 22, *a*), subequal prongs of urogomphi (fig. 22, *c*), and large number of setae, especially on medial aspect of femur and trochanter. The color pattern and lavish supply of setae give super-

ficial resemblance to the larva of *bipustulatus* (Linnaeus), which is readily separated on the basis of group characters.

Length 13.6 mm.; greatest breadth 2.75 mm. Fully distended larvae measured up to 18.5 mm. Conspicuous color pattern on dorsum (fig. 22, *a*) consists mainly of bright-brown or reddish-brown patches on pale yellow background, giving superficial appearance of four longitudinal dark bands. The darkest and most conspicuous coloring is on the anterior four-fifths of head, anterior two-thirds of prothorax, dorsal plate of ninth abdominal segment, and within the angle of impressions on mediotergites of first to eighth abdominal segments. The paramedial patches on first to eighth abdominal segments are large, irregular, and lighter in color. Dorsum slightly rugose; densely punctate on ninth abdominal segment; a few smaller punctures on other abdominal segments; head and prothorax minutely punctulate.

Maxillary palpus with fourth segment at least twice as long as third segment.

Setae even more abundant than in *rotundicollis*, being most significant in the following regions: Epicranial plates each bear 8 or 9 large setae near center of lateral area, usually arranged as a group of 5 or 6 setae with 1 seta farther dorsad and 2 setae farther anterad; each tergite of prothorax carries 35 to 50 setae; each mediotergite of mesothorax and metathorax bears 20 to 30 setae; medial aspect of femur with up to 8 slender setae; medial aspect of trochanter with 4 to 8 slender setae; each mediotergite of abdominal segments bears 15 to 25 setae; sternum of first to eighth abdominal segments bears up to 20 setae.

Sternum of first to eighth abdominal segments subquadrate, with a deep impression on each side which almost or entirely separates off laterosternites.

On ninth abdominal segment (fig. 22, *c*), lateral margins of dorsum bear 3 or 4 blunt "teeth"; area between pleurite and caudal notch is without punctures and approximates one-tenth (or less) of total length of segment, exclusive of urogomphi.

Urogomphi (*ur*, fig. 22, *c*; fig. 22, *e*) separate, bifid; prongs subequal and very finely punctulate. Inner prong (*ipr*) large, smooth, somewhat corniform; projecting backward, slightly inward and upward, with short, sharp tip turning abruptly upward; usually with 3 setae at base on ventrolateral aspect, at least 1 being near junction with outer prong. Outer prong (*opr*) large, smooth, subcylindrical, projecting caudodorsad, terminating bluntly rounded; 1 very minute seta on inner aspect about halfway along prong, 1 large seta on

anterolateral aspect of base and 1 large seta on lateral aspect of base or farther forward on undivided portion of urogomphus.

Caudal notch (*cn*) large, U-shaped, wider than long; anterior margin almost straight; wide posteriorly, but somewhat narrowed by tips of inner prongs.

Tenth abdominal segment with approximately 25 fine setae in irregular whorl; anal aperture T-shaped, with transverse portion to the rear.

Material used in study.—Examination was made of 15 specimens, all from Denmark. Some of the material had been used by K. L. Henriksen in his description of the species. Specimens examined are deposited in the U. S. National Museum and the Canadian national collection. Notes are given below concerning 2 reared specimens for which the larval exuviae and associated adults were available.

1; Dyrehaven, Denmark; Sept. 8, 1895; under bark of oak in pupal cell; E. Rosenberg. (U.S.N.M.)

1; Denmark; August 1915; in oak; J. P. Kryger. (U.S.N.M.)

LUDIUS BIPUSTULATUS (Linnaeus)

FIGURES 14, *c*; 22, *d*, *f*

Elater bipustulatus LINNAEUS, Systema naturae, ed. 12, vol. 1, p. 652, 1767.

Corymbites bipustulatus (Linnaeus), BOSE, Die Käfer Deutschlands von Valentin Gutfleisch, p. 363, 1859.

Selatosomus bipustulatus (Linnaeus), SEIDLITZ, Fauna Baltica, ed. 2, p. 171, 1888.

Corymbites (*Calambus*) *bipustulatus* (Linnaeus), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 385, 1927.

The only larva of this European species that was available for examination was collected under apple bark at Drochtersen, Germany. DuBuysson (1888, p. 15) refers to the larva as being exclusively carnivorous. Superficially it resembles larvae of the *Ludius rotundicollis* group.

The principal diagnostic characters of this species follow: Dorsum distinctly patterned (fig. 22, *f*) with dark brown patches over a pale yellow background; caudal notch large, U-shaped; urogomphi (*ur*, fig. 22, *d*) bifid, inner prongs much larger than outer prongs; tips of prongs bluntly rounded; nasale unidentate; proxistipes and dististipes not distinct; presternum of prothorax divided into 3 pieces; without spinelike setae on episterna of mesothorax and metathorax; mediotergites of abdominal segments with prominent setae unpaired

and transverse branches of impressions (*trim*, fig. 22, *f*) reaching to middorsal suture in second to eighth segments; sternum undivided in first 8 abdominal segments; and anal aperture linear and median.

Description of larva.—Length 9 mm.; greatest breadth 1.75 mm. on third to fifth abdominal segments. Only one larva was available for examination and its relative maturity is unknown. Body robust; convex dorsally, flatter ventrally; depressed dorsoventrally; with large membranes on lateral aspects; all segments broader than long; head and ninth abdominal segment about three-fifths greatest body width. Dorsum with conspicuous color pattern (fig. 22, *f*), consisting mainly of dark brown patches on pale yellow background, giving superficial appearance of 4 dark longitudinal bands. On first 8 abdominal segments the dark color all lies posterad to transverse branches of impressions and mediad to longitudinal branches; on each segment there are 2 subrectangular, paramedian patches connected anteriorly with lateral areas of similar pigmentation; remaining portions are pale yellow, except for brown, striate posterior margin of mediotergites and light brown area anterad to impressions. On ninth abdominal segment the dorsal plate and urogomphi are dark brown, dorsal plate somewhat paler laterally. On mesothorax and metathorax the dark coloring is less intense than on abdomen, but pattern is similar except laterally where there are 2 or 3 dark spots instead of 1 large patch. On prothorax the dorsal surface is light brown with somewhat suffused irregular dark brown areas, except for yellow-brown posterolateral patches and narrow medial area. Anterior two-thirds of head dark brown and frons dark throughout. Venter pale, unicolorous, except for dark urogomphi, ventral margin of caudal notch, and ventral mouthparts. Dorsum slightly rugose; sparsely punctulate, punctures most conspicuous on epicranial plates, prothorax, and ninth abdominal segment.

Head subquadrangular with arcuate sides; flattened above and below.

Frontoclypeal region extending backward to near foramen magnum, bluntly rounded posteriorly. Nasale unidentate. Subnasale with transverse ridge, ventrally convex, serrate when uneroded, bearing 5 subequal, short, sharp, forward-projecting denticles.

Epicranial plates punctulate. Dorsal sulci each bearing 5 setae, subequally spaced, the most anterior seta long, others small. Two pairs of lateroepicranial setae; also 1 seta farther dorsad and 1 small seta farther anterodorsad. Eye spot black, well defined, ovate or circular, surrounded by 4 or 5 setae, 4 conspicuous.

Gula elongate, narrowed in middle; glabrous.

Antenna with first segment clavate, three-fourths as wide as long. Second joint subcylindrical, almost as wide as long; one-half length of basal joint; on specimen at hand, right antenna with 1 large, conical "sensory" appendix, left antenna with 2 such appendices. Terminal segment as long as second joint and one-third as wide.

Mandibles about two-thirds as wide at base (ventral aspect) as long; retinaculum of moderate length. Distal half inward bending; pointed; outer surface convex with moderately deep dorsal groove; inner face slightly excavate with small median carina; ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts two-thirds as wide across bases of stipites as at anterior ends of stipites. Cardines slightly separated. Stipes large, wider anteriorly; proxistipes and dististipes not distinct; 4 setae on antero-lateroventral aspect. Galea with basal joint ring-shaped; half as long as terminal joint; terminal segment narrower than basal joint. Maxillary palpus with first segment ring-shaped; much wider than long. Second joint subcylindrical; as long as wide; longer than first joint and three-fourths as wide. Third segment ring-shaped; much wider than long; about one-half length of second joint. Fourth joint longer than wide; longer than third joint. Postmentum subrectangular with 1 long seta near each corner. First prementum with 2 or 3 setae just caudad to base of each palpus, making transverse row of 4 to 6 setae. Labial palpus with basal joint cylindrical, longer than wide, without setae; terminal joint small, more than one-half length and about one-half width of basal segment.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; one-third wider than long. Tergites minutely punctulate; with about 23 setae on each side of median dorsal suture arranged as follows: anteriorly with 10 to 12 setae in an irregular transverse row; posteriorly with 9 unpaired setae in transverse row, some minute, but mostly long; 3 setae along lateral part of tergite, the middle seta of the 3 being farthest mesad. Presternal area consisting of 3 sclerites as follows: 1 small posterior median sclerite, anteriorly attenuate; 2 large subtriangular lateral sclerites, striate on anterolateral aspect, with 1 stout seta laterad to center and a diagonal row of 4 minute setae on anteromedial aspect.

Mesothorax and metathorax each at least twice as wide as long. Mediotergites slightly rugose, punctures minute and sparse; transverse branches of impressions reaching about one-third distance from

longitudinal impressions to middorsal suture; longitudinal branches short, with 1 large seta (sometimes also 1 small seta) at posterior ends. Posterior part of each mediotergite with transverse row of 7 or 8 conspicuous unpaired setae. Lateral part of each mediotergite with 3 or 4 large setae. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Mesothoracic spiracles small, but slightly larger than spiracles in abdomen. Episternum without spinelike setae.

Legs subequal in length. Coxae of prothoracic legs with about 12 spinelike setae on each anterior surface, up to 17 such setae on coxae of mesothoracic and metathoracic legs; sometimes 1 stout seta and a few fine setae on posterior surface. Trochanter with 4 to 6 spinelike setae on medioanterior surface; 2 or 3 such setae and 1 fine seta on posterior surface; 2 long setae on medial aspect. Femur longer than trochanter and as wide; with 6 to 8 spinelike setae on medioanterior surface; 1 to 3 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; distally with 1 or 2 fine setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 2 or 3 spinelike setae and 1 slender seta on medioanterior surface; 1 or 2 spinelike setae and 1 slender seta on posterior surface. Ungula, when uneroded, about three-fourths as long as tibiotarsus; base well expanded mesally, with 2 fine setae arising mesally from small proximal sclerite.

First to eighth abdominal segments subequal; first segment practically as long as others; all segments about twice as wide as long; third to fifth segments widest. Mediotergites (*mtg*, fig. 22, *f*) with scattered minute punctures; transverse branches of impressions (*trim*) reaching to middorsal suture on second to eighth segments, only about half as long on first segment; longitudinal branches of impressions (*loim*) extending almost to posterior transverse row of setae. Each mediotergite with about 15 to 18 unpaired setae, arranged as posterior transverse row of about 12 setae (6 or 7 conspicuous), with 3 to 6 setae along lateral margin of sclerite. Laterotergite I bearing 3 to 5 setae. Spiracles small, subequal; spiracular sclerite small, ovate, usually just anterad to middle of segment. Pleurite well developed, subovate, slightly diminishing in size from first to eighth segments; posteriorly with 2 or 3 setae in transverse row. Sternum of 1 piece; subquadrate, narrower posteriorly; bearing about 8 setae.

Ninth abdominal segment (fig. 22, *d*), exclusive of urogomphi, slightly longer than eighth abdominal segment and three-fourths as wide; three-fourths as long as wide; widest anteriorly; width at an-

terior margin of caudal notch about three-fourths greatest width of segment. Dorsum convex, sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; sparsely punctulate; impressions indefinite, usual lateral pair practically obliterated by submarginal depressions; 2 faint paramedian impressions (*pim*) converge posteriorly, almost meeting; without setae except at lateral margins, which are raised and carinate, bearing 2 prominent blunt setiferous teeth (*to*) and 1 or 2 smaller teeth farther anterad and slightly more ventrad; transverse impression (*trim*) continuing completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; with from 15 to 18 setae on each side, some issuing from small sclerotized tubercles; distance between anterior margin of caudal notch and posterior margin of pleural area approximates one-fifth of total length of segment (exclusive of urogomphi). Pleural area transversely striate. Sternum of 2 sclerites, each with 5 setae.

Urogomphi (*ur*, fig. 22, *d*) large, separate, bifid, finely punctulate dorsally; projecting caudad; prongs unequal. Inner prong (*ipr*) large, projecting backward and slightly upward, terminating bluntly rounded; 1 prominent seta on ventrolateral aspect halfway along prong, issuing from a deep socket with raised anterior margin; 2 setae ventrally. Outer prong (*opr*) just a small round knob much like the blunt "teeth" on sides of dorsal plate; projecting dorsocaudad; 1 long seta issuing from apex and 1 short, fine seta from mesal aspect of base. Undivided part of urogomphus with 2 long setae, 1 ventrally and 1 just laterad to base of outer prong.

Caudal notch (*cn*) large, U-shaped, longer than wide.

Tenth abdominal segment with whorl of 10 fine setae and a few shorter hairs scattered over surface; anal aperture linear and median.

Material used in study.—The only larva available to the writer was received through the courtesy of Dr. Fritz van Emden, of the British Museum, London, in whose private collection it is stored. This larva was labeled "*Hypnoidus pulchellus* L. or *Selatosomus bipustulatus* L.?" However, Dr. van Emden kindly compared the illustrations prepared from this specimen with a larva and a larval skin (associated with an adult of *Corymbites bipustulatus* reared by C. O. Waterhouse) that he later found in the Museum collection. He states, "There can be no doubt whatever that this larval skin is conspecific with my larva, which you have figured."

THE LUDIUS NITIDULUS GROUP

FIGURES 13, *a*; 14, *i*; 23

KEY TO SPECIES

1. From North America; outer prongs of urogomphi about twice as large as inner prongs (fig. 23, *e*, *g*) 2
   From Europe; outer prongs of urogomphi not larger than inner prongs or only slightly larger (fig. 23, *f*) ....**nigricornis** (Panzer) (?) (p. 118)
2. Nasale and adjoining area of frons deeply sunken; nasale (fig. 23, *c*) narrow, tip divided into 3 narrow, forward-projecting denticles..... ....**rufopleuralis** Fall (?) (p. 117)
   Nasale and adjoining area of frons only slightly depressed; nasale (*n*, fig. 23, *a*) broad, tip tridentate, median denticle largest, lateral denticles projecting anterolaterad..........**nitidulus** (LeConte) (p. 112)

Knowledge of this group is based upon larvae of *nitidulus* (LeConte) and upon larvae that are believed to be *rufopleuralis* Fall or *aratus* (LeConte) and other unidentified larvae that are regarded as the European *nigricornis* (Panzer) or a closely related species.

From the fragmentary data that are available, the principal larval habitat appears to be the litter of the forest floor. The larvae are believed to be chiefly predaceous.

These larvae differ from other known *Ludius* larvae in possessing 2 conspicuous dorsal posteroepicranial setae (*ped*, fig. 23, *a*) on each side of the frontal sutures near the posterior limit of frons. In this they resemble the larvae of *Cryptohypnus*, *Melanactes*, and the Australian genus *Crepidomenus*. However, the *nitidulus* group is readily distinguished from these genera by the following combination of characters: Eyes present; outer urogomphal prongs (*opr*, fig. 23, *e*) curving forward; blunt "teeth" on the lateral margins of the dorsal plate of the ninth abdominal segment (*to*, fig. 23, *g*); abdominal mediotergites (fig. 23, *b*) without conspicuous transverse rugae and with impressions reaching to or almost to the middorsal suture on second to eighth segments; and setal pattern on abdominal mediotergites as figured.

The larvae are yellowish brown. Moderately large caudal notch, U-shaped. Urogomphi bifid; prongs subequal or outer prongs larger than inner prongs; tips of prongs sharp, tips of outer prongs inclined forward. Ninth abdominal segment (fig. 23, *g*) with 3 prominent blunt "teeth" on lateral margins of dorsum and typically with 4 setae on the central dorsal area. Nasale (*n*, fig. 23, *a*; fig. 23, *c*, *d*) with tip tridentate, denticles of varying character. Frontoclypeal area (fig. 23, *a*) broadly rounded posteriorly. Second joint of antenna bearing 1 sensory process. Gula of moderate width and length. Mandi-

bles much as in *aeripennis,* but in distal half the ventral margin of inner face is straight rather than slightly convex. Basal segment of each labial palpus with 1 to 3 setae. Eyes present. Presternum of prothorax divided into 2 pieces (fig. 13, *a*). Episterna of mesothorax and metathorax without spinelike setae. One seta (*atm,* fig. 23, *b*) on each side of middorsal suture (close to suture) in anterior half of each thoracic segment and in the first 8 abdominal segments. Mediotergites of abdominal segments 1 to 8 with prominent setae unpaired.

LUDIUS NITIDULUS (LeConte)

FIGURES 13, *a;* 14, *i;* 23, *a, b, e, g*

Corymbites nitidulus LECONTE, Trans. Amer. Philos. Soc., vol. 10, p. 439, 1853.
Ludius nitidulus (LeConte), BROWN, Canadian Ent., vol. 68, p. 18, 1936.

According to Brown (1936a, p. 19) this northern species is known from the Atlantic coast as far west as Edmonton, Alberta.

The larvae have been collected in New Brunswick from the litter under spruce, in northern Saskatchewan from leafy debris in well-established groves of aspen poplar (*Populus tremuloides*) and from the deep, damp litter under mixed stands of poplar, spruce, and paper birch. On August 10 an adult with its larval and pupal exuviae was found in its pupal chamber by the side of a poplar root about 1 to 1½ inches below the surface of the leaf litter.

The larva is readily distinguished from its nearest relatives as follows: Nasale and adjacent part of frons only slightly sunken; nasale (*n,* fig. 23, *a*) broad, lateral denticles short and projecting anterolaterad; and outer prongs of urogomphi (fig. 23, *e*) twice as large as inner prongs.

Description of larva.—Length 14.5 mm.; greatest breadth 2.5 mm., on fourth abdominal segment. The largest specimen examined measured 17.5 mm. but even this larva may not have been full grown. Body robust, with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum yellowish brown ("buckthorn brown," Ridgway, 1912); darker on mandibles, nasale, talus, and tips of prongs or urogomphi; venter slightly paler. Dorsum slightly rugose; sparse shallow pits; short, inconspicuous transverse rugae (or pits) just anterad to transverse branches of impressions on abdominal segments.

Head subquadrangular with slightly arcuate sides; flattened above and below.

Frontoclypeal region (fig. 23, *a*) with posterior part extending backward to or almost to foramen magnum (*for*); broadly rounded (almost truncate) posteriorly. Nasale and adjoining parts of frons only slightly sunken. Nasale (*n*) well developed; tridentate at tip; median denticle largest; lateral denticles appear as lateral expansions of median tooth; 1 robust seta arising from dorsal aspect of base of each lateral denticle. Subnasale with sclerotized transverse ridge, possibly serrate when uneroded, but no serration in material at hand, all of which has been badly eroded. Paranasal lobes produced beyond nasale.

Epicranial plates bearing small shallow pits. Two conspicuous dorsal posteroepicranial setae (*ped*, fig. 23, *a*), one on each side of frontal sutures near posterior limit of frons. Dorsal sulci with 5 setae subequally spaced, the most anterior seta very long, the next of moderate length and farthest laterad, others very small. Ventral sulci bearing row of 7 to 9 setae, usually 4 or 5 conspicuous. Two pairs lateroepicranial setae with 1 small or minute seta caudad to more ventral pair and sometimes a few minute setae scattered over lateral aspect of genae. Eye spot black; well defined, ovate or circular; surrounded by 4 or 5 setae; usually 1 additional seta short distance caudad to most dorsal of setae surrounding eye. Postgenal areas expanded mesally, sometimes almost meeting; 1 minute seta in area near ventral head ridge.

Gula of moderate length and width; glabrous.

Antenna with first joint clavate, two-thirds to three-fourths as wide as long; without setae; 3 or 4 small pores. Second segment subcylindrical, almost as wide as long; three-fifths length of basal joint; 1 or 2 pores; a few minute setae borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third segment. Terminal joint small, at least one-half length of second joint and about one-third as wide; 4 setae on apex.

Mandible of moderate length, robust, about two-thirds as wide at base as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending, pointed; outer surface convex with deep dorsal groove; inner face slightly excavate with small median carina; ventral margin of inner face sharp, straight or very slightly convex ventrally; dorsal margin of inner face sharp, strongly convex dorsally.

Ventral mouthparts three-fourths as wide across bases of stipites as across anterior ends of stipites. Cardines slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 5

or 6 prominent setae on antero-lateroventral aspect. Galea with basal joint subcylindrical, slightly shorter than terminal joint; terminal segment narrower than basal joint, a few pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment about as wide as long. Second segment as long as wide; slightly narrower than first joint; without setae; a few pores. Third joint wider than long; about one-half length of second segment; 3 or 4 pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 on lateral aspect. Fourth segment slightly longer than wide; fully as long as third joint; without setae or pores. Postmentum slightly wider anteriorly; 1 or 2 setae near each corner; 1 or more minute setae along each lateral margin. First prementum with 2 setae just caudad to base of each palpus, making transverse row of 4 setae. Labial palpus with basal joint subcylindrical, at least one-half length of first prementum, slightly longer than wide, 1 or 2 prominent setae distally on medioventral aspect, few pores; terminal segment about one-half length and one-half width of basal segment; without setae; usually with 1 pore.

Prothorax almost as long as combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites punctulate; anterior part of each tergite with 8 to 14 unpaired setae in irregular transverse row, 1 seta on each tergite being close to middorsal suture; posterior part of each tergite with 5 to 7 setae in irregular transverse row, 2 most medial setae usually paired or semipaired; 1 or 2 unpaired setae laterad to central areas of sclerite. Episternum with 3 large and a few small setae; 2 minute setae between episterna which almost meet mesally. Epimeron with 1 small seta. Presternal area (*prst*, fig. 13, *a*) consisting of 2 sclerites as follows: A small, posterior, median sclerite anteriorly attenuate, 2 setae anteriorly; and a large subtriangular sclerite (comprising the remainder of presternum) striate on anterolateral aspects, with 1 or 2 stout setae near each lateral margin, and anteriorly with 2 short diagonal paramedial rows each of 4 or 5 minute setae. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each at least twice as wide as long. Mediotergites with fine shallow punctures more abundant anteriorly, usually with minute setae in punctures; transverse branch of impression reaching about one-fourth to one-third distance from longitudinal branch to middorsal suture; longitudinal branch reaching almost one-half distance from transverse branch to posterior row of

setae. Anterior part of each mediotergite with 4 to 6 unpaired setae (in addition to the minute setae issuing from some of punctures), 1 seta being near middorsal line, 1 at end of transverse branch of impression, 1 within angle formed by branches of impression, 1 laterad to impression, and sometimes 1 or 2 additional small setae between end of transverse impression and seta near middorsal suture. Posterior part of each mediotergite with transverse row of 4 to 7 setae, at least the 2 most medial hairs are paired. Lateral part of mediotergite bears 1 or 2 setae in region between anterior and posterior rows. Anterior laterotergite subtriangular, one-half as large as posterior laterotergite. Episternum bearing 2 fine setae; without spinelike setae. Eusternum with up to 6 fine setae in transverse row anterior to bases of coxae, only 2 to 4 conspicuous. Mesothoracic spiracle slightly larger than spiracles in abdomen; spiracle in first abdominal segment sometimes about same length.

Legs subequal in length. Coxa with up to 28 spinelike setae and 1 or 2 fine setae on anterior aspect, some of spinelike setae noticeably long; a few scattered hairs (some stout) on posterior surface. Trochanter with 6 to 8 spinelike setae on medioanterior surface; 5 to 8 such setae and 1 fine seta on posterior surface; 2 well-developed hairs on medial aspect. Femur about as long and as thick as trochanter; usually with 8 to 10 spinelike setae on medioanterior surface; 3 to 5 spinelike setae and 1 slender seta on posterior surface; 1 or 2 long setae on medial aspect; a few fine setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 5 or 6 spinelike setae and 1 slender seta on medioanterior surface; 3 to 5 spinelike setae and 1 fine seta on posterior aspect. Ungula more than one-half length of tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth and fifth segments usually widest. Mediotergites (fig. 23, *b*) with small shallow pits; usually with small transverse rugae (or pits) anterior to transverse branches of impressions; transverse branches of impressions (*trim*) reaching to or almost to middorsal sutures on second to eighth segments, shorter on first segment; longitudinal branch of each impression (*loim*) extending approximately three-fourths distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite with 5 conspicuous setae, 1 (*atm*) near middorsal suture, usually just caudad to impression, 2 issuing from transverse branch of impression, 1 farther caudad within angle formed by branches of impression, and 1 laterad to impression; usually additional minute setae within impression and in pits and rugae. Posterior part of each mediotergite with transverse

row of 6 to 9 unpaired setae, 4 to 7 long. Sometimes 1 minute seta at posterior end of longitudinal branch of impression. Laterotergite I extending length of segment; bearing 4 to 6 setae. Spiracles usually slightly larger in first abdominal segment, situated in anterior half of segment, in extreme posterior part of subovate spiracular sclerite, which is slightly wider than spiracle and considerably longer. Pleurite well developed, subovate, somewhat diminishing in size from first to eighth segment, with 2 or 3 setae. Sternum of 1 sclerite, subquadrate; impressions very faint, 2 lateral impressions sometimes appearing as pale membranous lines; with about 10 fine setae around margins.

Ninth abdominal segment (fig. 23, *g*), exclusive of urogomphi, about as long as eighth abdominal segment and three-fourths as wide; four-fifths as long as wide; tapering caudally, making width at anterior margin of caudal notch about two-thirds greatest width of segment. Dorsum convex anteriorly, flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly wrinkled; 4 faint longitudinal impressions, a paramedian pair (*pim*) which converge posteriorly, but do not meet, and 2 laterally (*lim*) which are very indefinite; sometimes with a shallow round depression near center; typically with 4 setae in central area, but highly variable; lateral margins slightly raised and carinate, bearing 3 prominent, blunt setiferous tubercles or "teeth" (*to*); transverse impression (*trim*) continuing completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 10 to 15 unpaired setae on each side, some issuing from small sclerotized tubercles; anteriorly on lateral aspect 1 or more transverse rows of shallow pits or rugae, usually bearing minute setae. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-sixth total length of segment (exclusive of urogomphi). Pleural area large, transversely striated. Sternum of 2 sclerites, separated anteriorly by medium suture and posteriorly by tenth abdominal segment; each sclerite with 6 to 8 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 23, *g;* fig. 23, *e*) separate, bifid, projecting dorsocaudad; outer prong (*opr*) larger than inner prong. Inner prong (*ipr*) small, projected mediocaudad and sometimes slightly dorsad, terminating in sharp, upturned tip; 1 long seta from lateral aspect and 1 or 2 setae ventrally near base. Outer prong (*opr*) about twice as large as inner prong, corniform, projecting upward with sharp tip curving forward and slightly inward; 2 long setae, 1 from lateral aspect of distal half of prong and 1 from strongly margined

socket on caudolateral aspect of base of prong; 3 or 4 short, fine setae (sometimes minute) scattered over prong, sometimes additional fine setae ventrally or laterally at base of prong. Undivided part of urogomphus with 1 large seta ventrally just anterad to bases of prongs. Caudal notch (*cn*) moderately large, U-shaped, usually slightly longer than wide; sometimes slightly narrowed posteriorly by tips of inner prongs.

Tenth abdominal segment with irregular whorl of about 20 fine setae sometimes arranged in 2 whorls each of about 10 setae; anal aperture linear and median.

Material used in study.—Three examples were examined, including the larval exuvium of one specimen found as an adult in its pupal cell. The adult was identified by W. J. Brown, of Ottawa.

3; Waskesiu Lake, Saskatchewan; Aug. 10, 1937; an adult and its larval skin were found together in the pupal chamber; Robert Glen. (C.N.C.)

LUDIUS RUFOPLEURALIS Fall (?)

FIGURE 23, *c*

Ludius rufopleuralis FALL, Bull. Brooklyn Ent. Soc., vol. 28, p. 188, 1933.

Three unidentified larvae from Fredericton, New Brunswick, bearing strong resemblance to the larva of *nitidulus* (LeConte) have been regarded as *rufopleuralis* Fall or *aratus* (LeConte), the only other North American species included by Brown (1936a, pp. 17-20) in his discussion of the *nitidulus* group.

Both of these species occur in New Brunswick and inhabit the regions of Canada and the United States from the Atlantic seaboard to Lake Superior, with *rufopleuralis* continuing as far west as Winnipeg, Manitoba.

The larvae were found in litter under spruce trees. Cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig), were abundant in this litter and it is probable that the larvae were feeding upon these and other insects.

These larvae may be distinguished from the European *nigricornis* (?) by having the outer prongs of urogomphi twice as long as the inner prongs, and from *nitidulus* by the following characters: Nasale and adjoining parts of frons deeply sunken; nasale (fig. 23, *c*) relatively narrow, with tridentate tip, denticles short and narrow and all projecting forward; first prementum with 3 setae just caudad to the base of each palpus, making a transverse row of 6 setae; and basal joint of each labial palpus bearing 2 or 3 setae ventrally. The largest larva examined measured 15 mm. in length, but it was not fully dis-

tended and probably not mature; 3.0 mm. across fourth abdominal segment.

The specimens examined were received through the courtesy of R. E. Balch and are deposited in the Canadian national collection.

LUDIUS NIGRICORNIS (Panzer) (?)

FIGURE 23, *d, f*

Elater nigricornis PANZER, Fauna Insectorum Germaniae Initia, fasc. 61, No. 5, 1799.

Corymbites nigricornis (Panzer), CANDEZE, Monographie des elatérides, vol. 4, p. 159, 1863.

Corymbites (Sclatosomus) nigricornis (Panzer), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 379, 1927.

On the basis of adult characters, the European species *nigricornis* (Panzer) has been found by Brown (1936a, pp. 17-19) and other taxonomists to be closely allied to the North American species that constitute the *nitidulus* group. For this reason, two unidentified larvae from Hildesheim and Dresden, Germany, which strongly resemble the known American larvae of this group, have been regarded as larvae of *nigricornis* or of a closely related species.

Nothing is known of the larval habits except that one of these specimens was found burrowing into a mushroom.

The chief distinguishing characters of these larvae are: Urogomphal prongs (fig. 23, *f*) subequal or outer prongs only slightly larger; nasale and adjoining area of frons deeply sunken, nasale being in lowest plane; nasale (fig. 23, *d*) with tridentate tip, all denticles narrow and subrectangular and pointing forward; and presternum of prothorax with posterior median piece reduced to a narrow elongate sclerite about one-half as large as in *nitidulus* (*prst,* fig. 13, *a*) and in *rufopleuralis* (?). The larger of the two specimens measured 21 mm. in length.

The specimens examined are the property of the British Museum and of Dr. van Emden.

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LUDIUS DIVARICATUS (LeConte)

FIGURES 12, *e;* 24

Corymbites divaricatus LECONTE, ♂, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 446, 1853.

Corymbites crassus LECONTE, ♀, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 440, 1853.

Ludius divaricatus (LeConte), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 427, 1932.

This species is widely distributed in the eastern United States. Leng (1920, p. 170 *"divaricatus* (Lec.)" and *"crassus* (Lec.)") records specimens from Pennsylvania to Georgia and larvae have been taken from as far west as Missouri.

The larvae are soil inhabiting, having been found in bluegrass sod and in clover fields. Blatchley (1910, p. 766) reports finding the adults on the foliage of oak, which location suggests that the typical habitat is woodland meadows. Judging from the date of emergence of reared adults it would appear that pupation occurs normally in early June, much earlier than with most species of *Ludius*. There are no records of this species injuring cultivated crops.

The larva has been described, with good figures, by Jewett (1939). It is the only *Ludius* larva examined in which the sternum of the ninth abdominal segment is of one sclerite. It is also the only *Ludius* combining the characters of a large caudal notch and an undivided presternum of prothorax. Other diagnostic features are found in the urogomphi (*ur*, fig. 24, *c*, *d*), dorsum of the ninth abdominal segment (fig. 24, *d*), nasale (*n*, fig. 24, *a*), mandible (fig. 24, *b*), absence of eyes, absence of impressions on thoracic tergites, and the long impressions on second to fifth abdominal segments. It appears to be an isolated species.

Description of a "mature" larva.—Length 17.0 mm.; greatest breadth 2.7 mm. on fourth abdominal segment; sometimes metathorax and first abdominal segment are widest. A fully distended larva measured 21.5 mm. Jewett (1939, p. 107) records average length as 21 mm. and width 3 mm. across thorax. Body robust; with large membranes on lateral aspect; segments broader than long, eighth abdominal segment sometimes as long as wide; head and ninth abdominal segment about two-thirds greatest body width. Dorsum yellowish brown or pale brown (near "raw sienna" or "buckthorn brown," Ridgway, 1912); head and ninth abdominal segment slightly darker, mandibles, nasale, talus, and prongs of urogomphi definitely darker; sclerotized parts of venter approximately of same color as dorsum. Dorsum slightly rugose, with a few small shallow pits.

Head short, subquadrangular with arcuate sides, flattened above and below.

Frontoclypeal region (fig. 24, *a*) relatively wide and short; posterior part extending backward to or almost to foramen magnum; truncate posteriorly. Two anterior nasosulcal setae (*nsa*) on each side of base of nasale. Nasale (*n*) well developed, tridentate at tip; median denticle large; acutely pointed when uneroded; lateral denticles small,

sharp, projecting forward from near base of median denticle. Subnasale without denticles or other special sclerotized structures. Paranasal lobes produced beyond nasale; each lobe bearing 3 setae (1 small).

Epicranial plates sparsely and finely punctulate, punctures observable only under high magnification. Dorsal sulci shallow, each with 4 or 5 setae subequally spaced, the most anterior seta being long, the next minute, sometimes wanting, others small. Ventral sulci bearing row of 5 to 7 setae, with 2 to 5 conspicuous. Two large unpaired lateroepicranial setae, sometimes with 1 or more fine, small or minute setae just caudad to each large hair. Eye spot absent; usual eye region bordered by 2 unpaired setae. Postgenal areas expanded mesad, almost meeting; glabrous.

Gula extremely short, narrowed posteriorly by converging postoccipital sutures which almost meet; glabrous.

Antenna with first joint clavate, one-half to two-thirds as wide as long; without setae; 3 to 6 small pores. Second segment subcylindrical, two-thirds as wide as long; two-thirds length of basal segment; 1 or 2 pores; a few small setae borne distally; 1 large conical "sensory" appendix just ventrad to base of third segment. Terminal segment small, barely half as long as second joint and one-quarter to one-third as wide; 4 setae on apex.

Mandibles (fig. 24, *b*) elongate; base narrow, width at ventral aspect of base only one-half total length of mandible; retinaculum (*ret*) relatively small; penicillus (*pen*) short, failing to reach base of retinaculum. Distal half long, inward bending, pointed, somewhat bladelike with inner margin sharp and slightly convex ventrally, outer margin thickened; dorsal surface flattened or slightly excavate; ventral aspect slightly convex.

Ventral mouthparts about three-fourths to four-fifths as wide across bases of stipites as at anterior ends of stipites. Cardines only slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 3 prominent setae on antero-lateroventral aspect. Galea 2-segmented; basal segment with ventral surface usually somewhat flattened, about as long as terminal segment, without setae or pores. Terminal joint narrower than basal segment, 4 to 7 faint pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First segment as long as wide; distally on mesoventral surface with 1 or 2 small pores and 1 small seta, sometimes additional pores ventrally near center of segment. Second segment longer than wide; longer than first joint and as wide; without setae; 2 or 3 pores. Third

segment almost as long as wide, about one-half length of second segment, bearing 2 to 4 pores ventrally; distally with 1 minute seta on lateral aspect. Fourth joint longer than wide, about as long as third joint, but narrower; 1 pore dorsally. Postmentum with 1 long seta at each corner; a few minute pores scattered along margins. First prementum with 1 large seta just caudad to base of each palpus. Labial palpus with basal segment at least one-half as long as first prementum; longer than wide; with 1 seta ventrally; sometimes 2 or 3 minute pores. Terminal segment shorter and much narrower than basal joint; without setae; usually with 1 or 2 pores.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites with a few small shallow pits; anteriorly with 4 setae, rarely 5 (on each side of median dorsal suture) in transverse row, usually arranged as 1 pair in the middle of the row and the most lateral and most medial setae unpaired, sometimes arranged as 2 pairs with an unpaired seta farther laterad; posterior part of each tergite with 3 setae in transverse row arranged as 1 unpaired lateral seta and 1 pair (1 short, 1 long) farther mediad; tergites glabrous between anterior and posterior rows of setae. Episternum with 1 large seta near center and 1 or 2 minute hairs near presternum. Epimeron bearing 1 small seta. Presternal area consisting of 1 large triangular sclerite; posteriorly acute; anterolateral aspects striate; 1 large seta near each side; anteriorly near midventral line are 2 short oblique rows, each of 3 or 4 minute setae. Eusternum small, membranous or faintly sclerotized; furcal pits well developed. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely and shallowly punctulate; impressions wanting. Anterior part of each mediotergite with 1 moderate-sized seta laterally and usually 10 to 20 very small setae scattered irregularly along anterior margin; posterior part of mediotergite with transverse row of 3 conspicuous setae, 1 near lateral margin and a pair farther mediad; glabrous elsewhere except for minute setae in some of pits. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Episternum bearing up to 10 prominent spinelike setae, usually somewhat scattered, but mostly in 1 row; sometimes also several minute fine setae. Mesothoracic spiracle about equal in size to spiracles in abdomen.

Legs subequal in length. Coxa with up to 25 spinelike setae on anterior aspect; several short stout setae and a few scattered hairs on

posterior surface. Trochanter with 5 to 8 spinelike setae on anteromedial surface; 6 to 12 such setae and 1 fine seta scattered on posterior surface; 2 well-developed setae on medial aspect. Femur usually with 5 to 7 spinelike setae on anteromedial surface; 3 to 7 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; a few fine setae on lateral surface. Tibiotarsus about as long as femur but narrower; 5 or 6 setae around distal margin; 2 or 3 spinelike setae and 1 slender seta on anteromedial surface; 2 or 3 spinelike setae on posterior surface. Ungula when uneroded about as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; in material at hand the first segment is widest in some specimens and the fourth segment widest in others. Mediotergites with a few small shallow pits; transverse branches of impressions slightly sinuate, on second to fifth segments reaching middorsal suture, failing to reach the suture on first, sixth, seventh, and eighth segments; longitudinal branch of impression extending one-half to three-fourths distance from transverse branch to posterior transverse row of setae, the length increasing from first to eighth segments. Anterior part of mediotergite bears several minute setae scattered along sclerite, mostly in front of transverse branch of impression; also 3 to 5 small, widely separated, unpaired setae arranged as follows: 1 near medial end of impression (usually slightly caudad to impression), sometimes 1 or 2 toward middle of transverse branch of impression, 1 larger seta farther laterad and caudad (equidistant from transverse and longitudinal branches of impression), and 1 laterally below longitudinal branch of impression. Posterior part of mediotergite with 5 setae in transverse row, arranged as 2 pairs and 1 unpaired hair farther laterad. Sometimes a few additional minute setae observable at high magnifications. Laterotergite I extending length of segment; usually bearing 3 setae. Spiracles subequal; borne in posterior part of very small spiracular sclerite situated in anterior half of segment, directly laterad to transverse branches of impressions on mediotergites. Pleurite well developed, subovate or subtriangular, bearing 2 to 4 setae; size diminishing from first to eighth segments. Sternum of 1 piece, subquadrate, narrower posteriorly, without definite impressions, bearing 6 to 10 conspicuous setae around margins, and sometimes additional minute setae.

Ninth abdominal segment (fig. 24, *c, d*), exclusive of urogomphi, shorter than eighth abdominal segment and three-fourths as wide; slightly wider than long; sides of anterior half subparallel, posterior

half tapering caudally making width at anterior margin of caudal notch about two-thirds to three-fourths greatest width of segment. Dorsum convex anteriorly, flatter posteriorly. Dorsal plate (*dpla*) irregularly wrinkled, sometimes with sparse, small, shallow pits some of which usually bear minute setae; 4 indistinct longitudinal impressions, 2 laterally and a paramedian pair; sometimes a short transverse depression in caudal half of segment; central area with 4 prominent unpaired setae; lateral margins not well defined, bearing 2 prominent, blunt, setiferous tubercles or "teeth" (*to*), the more posterior "tooth" being also more ventral; transverse impression (*trim*) continues across segment, almost reaching to pleuron; sometimes few small, stout setae issue from impression and from area in front of impression. Tergite (*tg*) continues uninterruptedly laterally and on posterior ventral surface; usually with about 10 setae on each side. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fourth to one-third total length of segment (exclusive of urogomphi). Pleural area (*pl*) large, transversely striated, sometimes with 1 tiny seta on each side near anterior end. Sternum (*st*) of 1 sclerite, tenth abdominal segment (*10*) emerging from posterior part; bearing many minute setae scattered over sclerite and 6 to 10 larger setae, mostly near margin bordering tenth segment.

Urogomphi (*ur*, fig. 24, *c*, *d*) long, diverging, bifid; outer prong many times larger than inner prong. Inner prong (*ipr*) very small, corniform; appearing as a sharp, horny "tooth" on inner aspect of base of outer prong; projecting caudomediad, at right angle to outer prong; tip usually curving upward; with 2, sometimes 3, prominent setae at base of prong or at junction with outer prong. Outer prong (*opr*) very large, corniform; projecting latero-caudodorsad, curving upward and forward, terminating in sharp, horny point; bearing 1 or 2 prominent setae laterally near base of prong; sometimes a few small or minute setae scattered over proximal part of prong. Undivided part of urogomphus at least three-fourths as long as outer prong; bearing 1 prominent seta ventrally a short distance from junction of prongs; sometimes 1 short seta laterally just anterad to base of outer prong.

Caudal notch (*cn*) large, V-shaped; narrowed posteriorly by inner prongs.

Tenth abdominal segment (*10*) with a whorl of 10 fine setae; anal aperture linear and median.

Material used in study.—Sixteen examples were examined, including eight whole larvae and the exuviae of eight other specimens, which are believed to have been reared. Only five reared adults were located. These were identified by M. C. Lane, of Walla Walla, Wash., and W. S. Fisher, of the U. S. National Museum. The material is from 3 States: Kentucky (13); Clarksville, Tenn. (2); and Cadet, Mo. (1). Reared material for which associated adults are available is listed below.

6; Louisville, Ky.; Apr. 29, 1916; all believed to have been reared, but only 3 adults found. (U.S.N.M.; reared adults in W. W. collection, bearing accession numbers 6154, 6155, 6161.)

6; Lexington, Ky.; Feb. 17, 1938; 2 reared to adults. This material was received from H. H. Jewett, Agricultural Experiment Station, Lexington, Ky., and is believed to be part of the material used by him in his description of this species. (Larval material in Canadian national collection; adults probably in Experiment Station collection, Lexington.)

THE LUDIUS CUPREUS GROUP

FIGURES 14, *g*; 25, *a*, *d*, *e*, *g*, *h*

KEY TO SPECIES

1. From Europe or Asia.. 2
   From North America.........................**kendalli** (Kirby) (p. 134)
2. Prongs of urogomphi subequal in length (fig. 25, *h*).................. 3
   Outer prongs at least twice as long as inner prongs;[10] central Europe...
   ....**virens** (Schrank) (p. 133)
3. Not from Denmark.. 4
   From Denmark[11]......................**pectinicornis** (Linnaeus) (p. 131)
4. Mediotergites of abdominal segments (fig. 25, *d*) usually with moderately coarse pits, especially on each anterior half; each mediotergite of seventh and eighth abdominal segments (fig. 25, *d*) with posterior transverse row of 7 or more setae; found at altitudes from sea level to several thousand feet... ....**cupreus** (Fabricius) (p. 126)
   Mediotergites of abdominal segments usually with smaller pits; each mediotergite of seventh and eighth abdominal segments usually with posterior transverse row of 5 to 7 setae; usually below altitudes of 800 feet........................**pectinicornis** (Linnaeus) (p. 131)

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[10] According to Beling (1884, p. 208, "*Corymbites aeneicollis* Olv.").

[11] According to Rye (1906, pp. 100-101) *pectinicornis* is the only species of this group inhabiting Denmark.

Knowledge of this group is based upon an examination of larvae of the American species *kendalli* (Kirby), and the European *cupreus* (Fabricius) and *pectinicornis* (Linnaeus) and upon Beling's description of *virens* (Schrank).

These larvae are entirely soil inhabiting. Pupation occurs in an earthen cell in late July or early August. Transformation to the adult state is completed in from 2 to 4 weeks, but the beetle overwinters in its pupal chamber. The larvae of at least two of these species are known to be serious pests of crops for 2 or 3 years after their natural habitat has been brought under cultivation.

The group is very homogeneous and readily distinguished by the combination of extremely small abdominal pleurites (*pl*, fig. 25, *e*) and the presence of spinelike setae on the episterna of the mesothorax and metathorax. Among the known *Ludius* larvae there is no group that is closely related to *cupreus*. Superficial resemblance is found in the larva of *appressus* (Randall), but separation is accomplished readily through the urogomphi (fig. 25, *g*, *h*), subnasale (fig. 25, *a*), impressions on abdominal segments (fig. 25, *d*), and setation of the episterna of mesothorax and metathorax.

When mature, the larvae usually exceed 20 mm. in length. Dorsum yellowish brown to very dark brown. Caudal notch small, subovate, nearly closed posteriorly. Urogomphi bifid; prongs subequal in length or outer prongs longer (*virens*); inner prong broad, outer prong corniform with sharp tip usually inclined forward. Ninth abdominal segment (fig. 25, *h*) without median dorsal groove; with 2 setae (rarely 4) on central dorsal area; 3 "teeth" (*to*) on lateral margins of dorsal plate; and distance from pleurite to anterior margin of caudal notch approximately one-fifth to one-fourth total length of segment, exclusive of urogomphi. Nasale unidentate. Subnasale (fig. 25, *a*) with transverse row of from 14 to 17 denticles. Frontoclypeal area truncate posteriorly. Eyes present. Gula short, narrow. Mandible robust, much as in *aeripennis* group. Second segment of antenna with 1 "sensory" appendix. Basal segment of labial palpus without setae. Presternum of prothorax divided into 4 sclerites. With few (up to 4) spinelike setae on episterna of mesothorax and metathorax. Mediotergites of abdominal segments (fig. 25, *d*) with transverse branches of impressions reaching from one-half to two-thirds distance from longitudinal branches to middorsal suture and with prominent setae unpaired or semipaired. Sternum undivided in first 8 abdominal segments. Spiracles in anterior half of each segment.

LUDIUS CUPREUS (Fabricius)

FIGURE 25, *a, d, e, g, h*

Elater cupreus FABRICIUS, Species Insectorum, vol. 1, p. 268, 1781.
Ludius cupreus (Fabricius), ESCHSCHOLTZ, *in* Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.
Corymbites cupreus (Fabricius), LATREILLE, Ann. Soc. Ent. France, vol. 3, p. 150, 1834.—SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 359, 1927.

Preserved larvae of the typical *cupreus* and of its color form, *aeruginosus* (Fabricius), were examined. The two forms were found to be indistinguishable. The larva of the typical *cupreus* has been described by Xambeu (1895-1896, pp. 87-88; 1912, pp. 156-160) and by Roberts (1922, pp. 321-323), and the *aeruginosus* larva by Beling (1883, pp. 270-272) and by Saalas (1923a, pp. 125-128).

Saalas (1923a, pp. 128-129) gives a detailed account of the distribution of both forms. These occur widely in temperate and central Europe and are known from several points in Siberia. Only the typical *cupreus* is recorded from Turkestan and Norway, and both are absent from Denmark and Sweden. Both forms are known from the low countries of Holland and Belgium, but Slater (1869, p. 276) indicates that this species prefers higher altitudes, and Xambeu (1912, p. 159) reports specimens occurring at 2,200 meters above sea level.

Roberts (1922, p. 321) describes *cupreus* as a mountain-loving species, common in higher-lying districts of Great Britain and Ireland where the larvae are found in turf and under stones, *aeruginosus* generally being found along with the typical form. Beling (1883, p. 272) reports *aeruginosus* larvae as occurring in forests, preferably in sunny, dry places under moss, and frequently in association with the larvae of *Ludius aeneus* and *Limonius aeneoniger*. Xambeu (1912-1914) found *cupreus* larvae feeding on larval *Aphodius*. Roberts (1922) observed them feeding, in captivity, upon the roots of various plants and considers it probable that the species might cause minor damage in Great Britain. Saalas (1923a) and Linnaniemi (1935) report *aeruginosus* as an important pest of cereal crops in Finland, where it is chiefly encountered in old grassland of clay or sandy loam soils and only to a minor degree in marshy or very sandy soils. Injury is most marked during the first 2 years after grassland has been brought under cultivation.

Because of individual variation, structural characters are not wholly reliable for separating *cupreus* larvae from the very similar larvae of *pectinicornis* and *kendalli*. However, a typical larva of *cupreus* may

be characterized as follows: Up to 25 mm. in length; mediotergites of abdominal segments (fig. 25, *d*) moderately punctate anteriorly; each mediotergite of seventh and eighth abdominal segments (fig. 25, *d*) with posterior transverse row of 7 or more setae; 5 conspicuous setae on antero-lateroventral aspect of stipes.

Description of "mature" larva (form *aeruginosus*).—Length 21 mm.; greatest breadth 3.0 mm. on fourth abdominal segment. Largest larvae examined measured up to 3.25 mm. in width; Saalas (1923a, p. 125) and Beling (1883, p. 270) report specimens attaining 25 mm. in length. Body robust, with small membranous areas laterally; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum yellowish brown to dark brown, probably near "amber brown" (Ridgway, 1912) or paler in living specimens, but usually much darker in preserved specimens examined; head and prothorax usually slightly darker; Saalas (1923a, p. 126) and Beling (1883, p. 271) state that the ninth abdominal segment is of lighter color; venter somewhat paler than dorsum. Dorsum slightly rugose; segments punctate anteriorly, punctation varying from few small punctures to many moderate-sized punctures.

Head subquadrangular with arcuate sides; flattened above and below.

Frontoclypeal region with posterior part extending backward to foramen magnum; truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (*n*, fig. 25, *a*) unidentate, terminating sharply when uneroded. Subnasale (*sn*) consisting of transverse ridge, anteriorly convex, finely serrate when uneroded, with from 14 to 17 subequal, short, sharp, forward-projecting denticles. Paranasal lobes produced beyond nasale, each bearing 3 setae (1 small), sometimes additional minute setae.

Epicranial plates sparsely and finely punctulate. Dorsal sulci shallow, each with 5 setae subequally spaced, the most anterior seta very long, the next moderately long, others small. Ventral sulci bearing row of 6 to 9 setae, usually 2 to 5 conspicuous. Two large unpaired lateroepicranial setae. Eye spot black, ovate or circular; bordered by 2 conspicuous setae and sometimes a third minute hair. Postgenal areas expanded mesally, almost meeting; glabrous.

Gula short, narrowed posteriorly; goblet-shaped; glabrous.

Antenna with first segment weakly clavate; two-thirds to three-fourths as wide as long; without setae; 3 or 4 small pores. Second joint subcylindrical, barely as wide as long; three-fifths length of basal segment; 1 or 2 pores; a few minute setae or pegs distally; 1 medium-

sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, barely one-half as long as second joint and about one-fourth as wide; 4 setae on apex.

Mandibles of moderate length, robust, about two-thirds to three-fourths as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with deep dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts at least four-fifths as wide across bases of stipites as across anterior ends of stipites. Cardines slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 5 prominent setae on antero-lateroventral aspect. Galea with basal segment subcylindrical, slightly shorter than terminal segment, without setae or pores; terminal joint narrower than basal segment, outer surface longer than inner surface, 5 to 7 pores on lateroventral aspect. Maxillary palpi with all joints subcylindrical. First joint wider than long; distally on mesoventral surface with group of 5 to 8 small pores and 1 large and 1 small seta, sometimes 1 or 2 additional minute setae. Second segment as long as wide; as long as first joint and three-fourths as wide; without setae; 2 to 4 pores. Third joint almost as long as wide; about one-half length of second segment; with 2 or 3 pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 near lateral margin. Fourth segment as long as wide; more than one-half length of third joint; without setae or pores. Postmentum with 1 long seta near each corner and sometimes 1 small seta short distance caudad to each long anterior hair; few minute pores. First prementum with 2 large setae just caudad to base of each palpus, making transverse row of 4 hairs. Labial palpus with basal joint cylindrical, about one-half length of first prementum, longer than wide, without setae, with 5 or 6 pores; terminal segment approximately one-half length and less than one-half width of basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites minutely punctulate; anterior part of each tergite usually with 6 to 8 setae in transverse row, only 2 most medial setae always paired, others variable, sometimes in semipaired arrangement; posterior part of each tergite usually with 5 or 6 setae in transverse row, 2 most medial setae always paired, 2 most lateral setae often paired or semi-

paired. Episternum with 3 large setae. Epimeron bearing 1 small seta. Presternal area consisting of 4 sclerites as follows: A small posterior medial sclerite, anteriorly attenuate; 2 large, subtriangular lateral sclerites, striate on anterolateral aspect, with 1 stout seta laterad to center and a short diagonal row of 5 minute setae on anteromedial aspect; and a very narrow medial anterior piece. Eusternum small, membranous or weakly sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; transverse branch of impressions reaching about one-fourth distance from longitudinal branch to middorsal suture; longitudinal branch of impression short. Anterior part of each mediotergite with transverse row of 3 or 4 unpaired setae. Posterior part of each mediotergite with transverse row of 4 conspicuous setae, 2 most medial paired. Lateral part of each mediotergite with 1 large seta between anterior and posterior rows. Additional minute setae sometimes observable in punctures. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Episternum bearing up to 4 spinelike setae (usually 2 or 3). Mesothoracic spiracles slightly larger than spiracles in abdomen.

Legs subequal in length. Coxa with up to 25 spinelike setae on antrior aspect; 3 to 6 stout setae and a few fine hairs scattered on posterior surface. Trochanter with 6 to 9 spinelike setae on medioanterior surface; 6 to 8 such setae and 1 fine seta on posterior aspect; 2 well-developed setae on medial surface. Femur usually with 7 to 10 spinelike setae on medioanterior surface; 3 or 4 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine hairs on lateral surface. Tibiotarsus with 6 setae around distal margin; 3 or 4 spinelike setae and 1 slender seta on medioanterior surface; 2 or 3 spinelike setae on posterior aspect. Ungula well developed; when uneroded about as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (fig. 25, *d*) with small shallow punctures, especially in anterior half, usually more pronounced between end of transverse branch of impression and middorsal suture, punctation varying from few small punctures to many moderate-sized pits, usually moderately pitted and becoming stronger from first to eighth segments; transverse branch of impression (*trim*) slightly sinuate, reaching from one-half to two-thirds distance from longitudinal branch to middorsal suture on second to eighth segments, from one-third to one-half distance on first segment; longitudinal

branch of impression (*loim*) extending approximately three-fourths distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite with 4 (rarely 5) setae arranged as follows: 1 at end of transverse branch of impression, 1 toward middle of transverse branch, 1 larger seta laterad to longitudinal branch of impression, and another large seta near center of sclerite equidistant from branches of impression; rarely with a minute seta between end of transverse branch of impression and middorsal suture. Posterior part of each mediotergite with transverse row usually of 5 setae on more anterior segments, increasing to between 7 and 10 setae on seventh and eighth segments (sometimes also on sixth and fifth segments); setae not definitely paired, but 4 most medial hairs frequently in semipaired arrangement; in the more posterior segments some of the additional setae are placed between the primary hairs and slightly farther caudad. Laterotergite I (*ltg I*, fig. 25, *e*) extending length of segment, with 3 setae. Spiracles subequal in size, situated in posterior end of subovate sclerite, which is slightly wider than spiracle and 2 to 2½ times as long; in anterior half of segment. Pleurites (*pl*) inconspicuous; reduced to extremely narrow, elongate sclerite usually infolded between laterotergite I and sternum; bearing 1 seta. Sternum (*st*) of 1 piece; subquadrate; without definite impressions or sutures; several setae along lateral margins, sometimes more abundant in eighth segment.

Ninth abdominal segment (fig. 25, *h*), exclusive of urogomphi, slightly shorter than eighth abdominal segment and three-fourths as wide; four-fifths as long as wide; sides of anterior half subparallel, posterior half tapering caudally making width at anterior margin of caudal notch about two-thirds greatest width of segment. Dorsum convex anteriorly, flatter posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined; sparsely punctulate anteriorly; 4 faint longitudinal impressions, 2 laterally (*lim*) and a paramedial pair (*pim*) which converge posteriorly but do not meet; with 2 long setae anteriorly, rarely with 2 small setae farther caudad; lateral margins slightly raised and carinate, bearing 3 prominent blunt setiferous tubercles or "teeth" (*to*); transverse impression (*trim*) usually interrupted in middle, rarely continuing completely across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 12 to 16 setae on each side, some issuing from small, sclerotized tubercles; anteriorly on lateral aspect with a transverse row, or a confused double row, of conspicuous pits. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fifth to one-fourth the total length

of segment (exclusive of urogomphi). Pleural area large, transversely striate. Sternum of 2 sclerites, separated anteriorly by median suture and posteriorly by tenth abdominal segment; each sclerite usually with 5 to 8 setae, mostly in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 25, *h*; fig. 25, *g*) robust, separate, bifid; directed caudad; prongs subequal in length but of different shapes. Inner prong (*ipr*) subtriangular, with strongly sclerotized, undate anteromedial margin; projecting mediad or caudomediad, sometimes slightly dorsad, terminating in sharp, horny point; 1 prominent seta issuing from posterior margin, just mediad to base of outer prong. Outer prong (*opr*) corniform; projecting dorsad or caudodorsad with sharp tip curving upward, sometimes slightly forward; 1 prominent seta arising from anterior aspect of base of prong. Undivided part of urogomphus with 1 to 3 setae ventrally and 1 arising from small tubercle just laterad to base of outer prong.

Caudal notch (*cn*) small, subovate; longer than wide; narrowed posteriorly, sometimes closed, by converging inner prongs.

Tenth abdominal segment with about 20 fine setae arranged as 2 equal whorls; anal aperture linear and median.

Material used in study.—Three examples of the typical *cupreus* and 18 of the color form *aeruginosus* were examined. The typical *cupreus* were received from A. W. Rymer Roberts, of Cambridge University, Cambridge, England, and were used by him in preparing his description (1922) of this species. The *aeruginosus* larvae were all from Puolanka and Suomussalmi, Finland (Suomi), and were part of the material used by Prof. U. Saalas in his studies (1923a). The specimens examined are deposited in the Canadian national collection and the U. S. National Museum. Listed below is the material of the typical form that was associated with reared adults. Identification of reared specimens was checked by W. J. Brown, of Ottawa.

2; Windermere, Westend, England; Aug. 5, 1917; 1 reared to adult, Sept. 2, 1918. (C.N.C.)

LUDIUS PECTINICORNIS (Linnaeus)

Elater pectinicornis LINNAEUS, Systema naturae, ed. 10, vol. 1, p. 406, 1758.
Ludius pectinicornis (Linnaeus), ESCHSCHOLTZ, *in* Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.
Corymbites pectinicornis (Linnaeus), LATREILLE, Ann. Soc. Ent. France, vol. 3, p. 150, 1834.—SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 361, 1927.

Ludius pectinicornis, a European species, is unique in being the only species of the *cupreus* group to inhabit Denmark. Schiodte

(1870, p. 520) and Henriksen (1911, pp. 260-261) described the larva from that country and Beling (1883, pp. 268-270) from Germany. The larvae are reported to occur in soil in meadows, particularly in woodland meadows. Beling found one larva under moss in a beech grove. According to Slater (1869, p. 276) *pectinicornis* abounds at low altitudes, but decreases at elevations above 800 feet.

Structurally, this larva is virtually indistinguishable from the larvae of *cupreus* and *kendalli*. Minor differences in punctation, setation, and in urogomphi were observed between individuals of these species, but these characters proved to be so variable that when all the available material was examined no clear and constant difference remained. Beling and Henriksen record *pectinicornis* larvae measuring 28 mm. in length. This equals the largest known specimens of *kendalli* and exceeds by 3 mm. the largest *cupreus* larvae reported.

The mediotergites of the first 8 abdominal segments usually have small sparse punctures on each anterior half, the posterior half being less punctate, hence smoother, However, in some specimens the punctation is much coarser and resembles the typical condition found in *cupreus*. In general, setae are somewhat shorter and finer in *pectinicornis* than in *cupreus;* thus where *cupreus* has very small setae, *pectinicornis* usually has still smaller hairs, or, as in some cases, lacks such hairs. The most important setal characters are the following: On each mediotergite of the seventh and eighth abdominal segments, *pectinicornis* larvae have a posterior transverse row of 5 to 7 setae, rarely 8, *cupreus* larvae usually have a row of 7 to 10 setae; on the anterolateroventral aspect of stipes, *pectinicornis* usually has 4, rarely 5, conspicuous setae, *cupreus* usually has 5 such setae.

Beling (1884, p. 208), in his conspectus, separates the larva of *cupreus* (color form *aeruginosus*) from that of *pectinicornis* on the basis of stronger punctation and rugosity on the mediotergites of the abdominal segments. He distinguishes these species in a similar manner in his detailed descriptions (1883, pp. 269 and 271), but at the conclusion of his description of *pectinicornis* he states (p. 270) (translation): "With the meager research material which has been at my disposal so far, I am forced to leave the question open to doubt as to whether the difference previously mentioned, of wrinkling and pitting on the upper surface of the first eight abdominal segments of the larvae of *Corymbites pectinicornis* and *aeruginosus,* is constant and characteristic to the extent that it could serve for definite distinguishing of the two larvae in question." Saalas (1923a, p. 128) states (translation): "This larva [*cupreus,* form *aeruginosus*] is very simi-

lar to the larva of *Corymbites pectinicornis* except in a few respects; however, in many cases it is very difficult to separate the two larvae with certainty. In the *pectinicornis* larva the hind portions of the abdominal segments are smoother, with only very small, sparse punctures; the inner prongs of the cerci [*urogomphi*] are directed more posteriorly making the angle between the two prongs more acute than in *aeruginosus*, almost right-angled, in *aeruginosus* more obtuse. The larva of *pectinicornis* has, on the hind margins of the inner prongs, only a very small, almost indiscernible tubercle, in the larva of *aeruginosus* the tubercle is usually somewhat larger and broader."

In the present study, similar differences were observed in individual cases, but these characters were found to vary and to intergrade so much that no reliance could be placed upon them as specific characters.

Material used in study.—Eight larvae, six from Denmark and two from Finland (Suomi), were examined. These specimens formed part of the material available to Henriksen (1911) and Saalas (1923a) in their studies on this species. To the writer's knowledge, none of the material was associated with reared specimens. The larvae examined are deposited in the Canadian national collection, the Royal Veterinary and Agricultural College, Copenhagen, and the U. S. National Museum.

LUDIUS VIRENS (Schrank)

Elater virens SCHRANK, Schriften Berlinischen Gesell. naturf. Freunde, vol. 2, p. 317, 1781.
Elater aeneicollis OLIVIER, Journ. Hist. Nat, vol. 1, p. 264, 1792.
Corymbites virens (Schrank), HAROLD, Coleopteralogische Hefte, vol. 5, p. 92, 1869.—SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 363, 1927.

Larvae of this central European species were not available for examination in the present study and the remarks that follow are adapted from the writings of Beling (1883, pp. 265-268; 1884, p. 208), who described the larva under the name *aeneicollis* Olivier.

Larvae, apparently identified through rearing, were collected by Beling from moist soil under moss in the forests of Germany, beech and pine forests being mentioned specifically. According to his observations the larvae were confined to areas covered by deposits of century-old ore slag. Such areas were kept moist by nearby springs, but, as a rule, the vegetation was limited to mosses and a few characteristic flowering plants.

Ludius virens is readily separated from the other known larvae of the *cupreus* group by having the outer prongs of the urogomphi at least twice as long as the inner prongs. It also attains a greater length, reaching 30 mm.; width 3 mm. Dorsum very dark brown (black-

brown); venter reddish yellow or brownish yellow. Mediotergites of first 8 abdominal segments with moderately coarse punctures anteriorly, smoother posteriorly, thus resembling the typical sclupture of *cupreus* larvae. Ninth abdominal segment with sharp, elevated sides each bearing 3 short, sharp teeth of which the 2 most anterior are closer together and the middle tooth usually largest. Urogomphi bifid. Outer prongs pointed, directed upward and curving forward. Inner prongs broader, one-half (or less) as long as outer prongs, projecting toward each other. Caudal notch elliptical, longer than wide, posterior opening about one-third greatest width of sector.

LUDIUS KENDALLI (Kirby)

FIGURE 14, *g*

Ctenicerus kendalli KIRBY, *in* Richardson's Fauna Boreali-Americana, vol. 4, p. 149, 1837.
Elater anchorago RANDALL, Boston Journ. Nat. Hist., vol. 2, p 5, 1838.
Ludius virens of American authors, nec Schrank.
Ludius kendalli (Kirby), BROWN, Canadian Ent., vol. 71, p. 44, 1939.

Ludius kendalli is the only North American species belonging to the *cupreus* group. Larvae have been identified through rearing of both the typical form and an unnamed color form, the adult of which has the elytra entirely purplish.

According to Brown (1939, p. 44) the range of this species "is transcontinental, and extends from the northern limits of the subarctic forests south to Maine, the Lake Superior region, the prairies, and central British Columbia." Larvae have been collected in the north-central parklands of Saskatchewan, the typical and the darker forms occurring together. The larvae live in the soil and are most abundant in native grassy areas bearing a growth of young willow. This species causes severe injury to garden and field crops for about 3 years after such areas are brought under cultivation. The species has not been taken from the open prairie regions of the Prairie Provinces.

In structure, *kendalli* is very similar to the larvae of *cupreus* and *pectinicornis*; hence identification is much more readily achieved on the basis of distribution.

Full-grown larvae measure up to 28 mm. in length and 3.75 mm. in greatest width. In the typical *kendalli*, the dorsum is usually yellowish brown, somewhat paler than in most *cupreus* larvae; in the unnamed color form the dorsum is darker, being similar in color to most *cupreus*. As in *pectinicornis*, the mediotergites of the first 8

abdominal segments bear sparse, small punctures, rarely as punctate as in the majority of *cupreus* larvae. In agreement with *cupreus,* each mediotergite on the seventh and eighth abdominal segments usually bears 7 or more setae in the posterior transverse row, and the stipes usually have 5 conspicuous setae on the antero-lateroventral aspect. Urogomphi (fig. 14, *g*) as figured.

Material used in study.—Examination was made of 29 specimens, including the larval exuviae of 5 reared specimens. The reared adults were identified by W. J. Brown, of Ottawa. All material is in the Canadian national collection. Specimens associated with reared adults are listed below:

3; Spalding, Saskatchewan; July 9, 1927; 1 reared; N. J. Atkinson.
5; Spalding, Saskatchewan; June 19, 1930; 2 reared; R. Glen.
13; Naicam, Saskatchewan; July 8, 1930; 2 reared; Albert Johnson.

LUDIUS APPRESSUS (Randall)

FIGURES 14, *a, b;* 25, *b, c, f*

Elater appressus RANDALL, Boston Journ. Nat. Hist., vol. 2, p. 11, 1838.
Corymbites appressus (Randall), LECONTE, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 446, 1853.
Ludius appressus (Randall), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 420, 1932.

The distribution of this rather rare North American species is given by Van Dyke (1932, p. 396) as "Lake States to Nova Scotia and Maine." The only larvae known were collected from decomposing litter under spruce in Quebec and New Brunswick. Larvae of this species were observed by R. F. Morris, of Fredericton, New Brunswick, to feed upon the cocoons of the European spruce sawfly, *Gilpinia hercyniae* (Hartig). One specimen that was reared to maturity transformed to the adult stage during August.

The brief description that follows was first prepared from the badly broken larval skin of the reared specimen. Subsequently it was checked by examination of whole larvae.

Ludius appressus is not closely allied to any of the known species of *Ludius,* but the larva bears superficial resemblance to those of the *cupreus* group. Separation is secured through differences in urogomphi (fig. 25, *c, f*), subnasale (fig. 25, *b*), and setation of episterna of mesothorax and metathorax.

Larva brown, unicolorous; dorsum punctulate or sparsely punctate, pits shallow. Probably attaining or exceeding 20 mm. in length when

full grown. Caudal notch small, ovate. Urogomphi bifid; prongs rather short, subequal in length and sharply pointed; inner prong (*ipr*) with a strongly sclerotized protuberant inner margin. Three small rounded "teeth" on each lateral margin of dorsal plate of ninth abdominal segment. Nasale (*n*, fig. 25, *b*) of 1 pointed tooth. Subnasale (*sn*) with 1 large central tooth and numerous fine denticles laterally. One "sensory" appendix on second segment of antenna. Mandible short, robust; distal half with prominent expansion of dorsal margin of inner surface. Gula short and relatively narrow. Eyes present. Frontoclypeal region extending backward to foramen magnum; truncate posteriorly. Prosternum divided into 4 sclerites. Without spinelike setae (rarely with 1 seta) on episterna of mesothorax and metathorax. First 8 abdominal segments with short impressions, transverse branches reaching one-fourth to one-third of distance from longitudinal branches to middorsal suture; prominent setae unpaired; pleurites very small (as in fig. 25, *e*) and usually difficult to observe; sternum undivided; spiracles subequal in size and situated in anterior half of each segment.

Material used in study.—Three specimens, two larvae from New Brunswick and the last larval exuvium of a reared specimen, were examined. The reared adult was identified by W. J. Brown, of Ottawa.

1; Cascapedia River, Quebec; Aug. 26, 1935; reared to adult; M. L. Prebble. (C.N.C.)

* * *

LUDIUS RESPLENDENS AERARIUS (Randall)

FIGURES 11, *b*, *f*; 13, *b*; 26

Ludius resplendens ESCHSCHOLTZ, *in* Thon's Entomologisches Archiv, vol. 2, p. 34, 1829.
Elater aerarius RANDALL, Boston Journ. Nat. Hist. vol. 2, p. 7, 1838.
Diacanthus racinei CHEVROLAT, Rev. Mag. Zool., p. 578, 1852.
Corymbites viridis GERMAR (nec Say), Zeitschr. fur die Ent., vol. 4, p. 61, 1843.
Ludius resplendens aerarius (Randall), BROWN, Canadian Ent., vol. 71, p. 45, 1939.

In addition to the typical *resplendens*, Brown (1939, p 45) recognizes two subspecies, *breweri* (Horn) and *aerarius* (Randall). Combining the information given by Brown, Leng (1920, p. 169) and Van Dyke (1932, p. 425), the distribution is as follows: the typical *resplendens* is found along the mountains from Alaska to California; at its southern limits it is replaced by *breweri* and along the mountains of western Alberta it intergrades with the eastern *aerarius*,

which continues through to the New England States, eastern Canada, and Newfoundland.

Larvae of *resplendens aerarius* (Randall) have been collected in Alberta, Saskatchewan, and Manitoba. The other forms of the species are not known in the larval stage. All remarks that follow apply only to the subspecies *aerarius*.

The larvae inhabit wooded areas, apparently being present in practically every well-established poplar bluff in the Prairie Provinces, as well as in all extensive forests. Specimens have been taken from decaying stumps and logs of poplar, willow, and pine, but are usually more abundant in the leaf litter beneath such trees. The species is obtained occasionally from native shrub thickets. In the late autumn, larvae have been found in the soil, just under the litter, probably in preparation for hibernation.

The species is not known to be of economic importance. In captivity a larva was observed to attack and partially devour a cutworm. A wood-feeding habit is also suggested from finding in a fresh burrow in a chip of wood a larva with its head at the blind end of the tunnel. Pupation and ecdysis usually take place in cells made in wood. The pupa appears in late July and, under laboratory conditions, transforms to the adult in about 12 days. All adults found in late autumn were in twigs, logs, and stumps, many still within their pupal chambers.

In structure, the larva of *resplendens aerarius* exhibits fundamental *Athous* and *Elathous* characters, but does not fall in any known "species group." It is most readily identified by the ninth abdominal segment (fig. 26, *f*), especially by the blunt outer prongs of urogomphi (*opr*, fig. 26, *e, f*), the small caudal notch (*cn*), the median dorsal groove (*mg*), and the blunt "teeth" (*to*) on the margins of the dorsum. Valuable supplementary characters are the yellow-brown color; the abdominal mediotergites (fig. 26, *c*) with long impressions, but lacking other prominent sculpture; the presence of eyes; tridentate nasale (fig. 26, *a*); shape of the base of the ungula (fig. 26, *d*); and the presence of several minute setae just behind the large anterior seta in each dorsal head sulcus (fig. 26, *b*).

Description of "mature" larva.—Length 21 mm.; greatest breadth 2.75 mm. on fourth abdominal segment. Fully distended larvae measured up to 23 mm. Body robust, with large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about two-thirds greatest body width. Dorsum yellowish brown (near "amber brown," Ridgway, 1912), mesothorax, prothorax, and head somewhat darker, mandibles, nasale, talus, and prongs of urogomphus considerably darker; venter slightly paler,

except on head. Dorsum slightly rugose, with scattered, small, shallow pits.

Head subquadrangular, with arcuate sides; flattened above and below.

Frontoclypeal region with posterior part extending backward to foramen magnum, truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (*n*, fig. 26, *a*) of 1 well-developed tooth extending from one-half to three-fourths as far forward as paranasal lobes, terminating in 3 subequal denticles, lateral denticles projecting anterolaterad; sometimes eroded to appear as a single blunt tooth. Subnasale (*sn*) consists of many fine, sharp, forward-projecting denticles on basal part of nasale; sometimes 50 or more such denticles, but number highly variable; frequently much eroded. Paranasal lobes produced beyond nasale, each bearing 3 or more setae (only 2 prominent).

Epicranial plates sparsely and finely punctulate. Dorsal sulci (fig. 26, *b*) each with 1 very long anterior seta followed by a scattered group of 2 to 7 extremely minute setae (usually 4 or 5), 1 of which is always found just laterocaudad to the large anterior hair; in posterior part of sulcus are 3 small, subequally spaced setae. Ventral sulci with row of 7 to 10 setae, usually about 4 conspicuous. Two long unpaired lateroepicranial setae. Eye spot black, well defined, ovate or circular; surrounded by 3 or 4 setae, only 2 conspicuous. Postgenal areas expanded mesally, almost meeting, usually with 1 minute seta centrally located.

Gula short, narrowed posteriorly by converging postoccipital sutures, goblet-shaped, glabrous.

Antenna with first joint weakly clavate, two-thirds to three-quarters as wide as long; without setae; 2 or 3 small pores. Second segment subcylindrical, two-thirds to three-quarters as wide as long; about three-fifths length of basal joint; 1 or 2 pores; a few minute setae or pegs borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, at least half as long as second joint and about one-third as wide; 4 setae and some "sensory" pegs on apex.

Mandible of moderate length, robust; two-thirds to three-fourths as wide at base (on ventral aspect) as long; retinaculum very well developed, more than one-third length of distal half of mandible; penicillus present, sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with short, deep, dorsal groove; inner face slightly excavate with small median carina,

ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and strongly convex dorsally.

Ventral mouthparts from three-fourths to four-fifths as wide across bases of stipites as at anterior ends of stipites. Cardines only slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 4 or 5 prominent setae on antero-latero-ventral aspect. Galea with basal joint subcylindrical, shorter than terminal segment, without setae or pores; terminal joint about as wide as basal joint, outer aspect longer than inner aspect, 2 or 3 pores on lateroventral surface. Maxillary palpi with all joints subcylindrical. First segment slightly wider than long, with ventral surface shorter than other surfaces; distally on mesoventral surface with group of 3 or 4 small pores and 2 setae; 1 or 2 pores near middle of ventral aspect. Second segment nearly as long as wide; as long as first segment and almost as wide; without setae; 1 or 2 pores. Third joint about as long as wide; at least one-half length of second joint; two pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 near lateral aspect. Fourth segment longer than wide; about as long as third joint; 1 minute seta on dorsal surface. Postmentum with 1 long seta at each corner; 1 small seta short distance caudad to each long anterior hair; minute pores and sometimes 1 or 2 additional small setae along lateral margins. First prementum with 1 large and 1 small seta just caudad to base of each palpus, forming transverse row of 4 hairs. Labial palpus with basal joint about one-half as long as first prementum, as long as wide, without setae, 3 or 4 pores; terminal segment about three-fourths length and one-half width of basal segment, without setae, usually with 1 pore.

Prothorax about three-fourths combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites minutely punctulate; without well-defined impressions, but each tergite with narrow pale line (sometimes branched) beginning near middle of middorsal suture and running cephalolaterad across about one-third of tergite; anterior part of each tergite with about 9 prominent setae in transverse row, usually arranged as 3 pairs and 3 unpaired hairs, the most lateral seta usually unpaired; posterior part with 5 or 6 prominent setae in transverse row, arranged as 3 pairs or 2 pairs and 1 unpaired; glabrous elsewhere except for few minute setae issuing from some of punctures. Episternum with 3 conspicuous setae. Epimeron bearing 1 small seta. Presternal area of 1 large, triangular sclerite, posteriorly acute; striate on antero-

lateral aspects; 1 stout seta near each lateral margin and anteriorly near midline with 2 short rows each with 4 or 5 minute setae; a short sclerotized rod appears on the median line about one-fourth distance from anterior margin. Eusternum small, usually definitely sclerotized. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; transverse branch of impression reaching from one-fourth to one-third distance from longitudinal branch to middorsal suture; longitudinal branch of impression short. Anterior part of each mediotergite without setae except for a few minute hairs issuing from some of punctures. Posterior part of each mediotergite with transverse row of 3 to 6 setae; usually only 3 large, 2 of which are paired. One or 2 large unpaired setae and sometimes 1 small seta along margin of each mediotergite, laterad to impression. Anterior laterotergite subtriangular, almost as large as subovate posterior laterotergite. Episternum bearing up to 7 spinelike setae, usually from 3 to 5. Mesothoracic spiracle slightly larger than spiracles in abdomen.

Legs subequal in length. Coxa with up to 43 (usually about 30 to 35) spinelike setae on anterior aspect, usually a few less on prothoracic legs than on other legs; 4 to 8 stout setae and a few fine hairs on posterior surface. Trochanter with 8 to 12 (1 specimen with 16) spinelike setae on medioanterior surface; up to 12, rarely more, such setae and 1 fine seta on posterior surface; 2 to 4 well-developed setae on medial aspect. Femur usually with 7 to 12 (1 specimen with 14) spinelike setae on medioanterior aspect; 4 to 6 spinelike setae and 1 slender hair on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae laterally. Tibiotarsus with 6 setae around distal margin; 2 to 5 spinelike setae and 1 slender seta on medioanterior surface; 2 to 4 spinelike setae on posterior aspect. Ungula (*un*, fig. 26, *d*), when uneroded, about three-fourths as long as tibiotarsus; base expanded medially with distal end pointed (when uneroded) giving ungula appearance of bottle opener.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (fig. 26, *c*) with scattered, small, shallow pits; transverse branch of impression (*trim*) variable, but usually reaching to or almost to middorsal suture on segments 2 to 5, shorter in other segments, especially in first segment where it attains only about one-half distance to middorsal suture; longitudinal branch of impression (*loim*) extending approximately three-fourths distance from transverse branch to posterior

transverse row of setae. Anterior part of each mediotergite without prominent setae, but sometimes with a few minute hairs issuing from punctures and from transverse branch of impression. Posterior part of each mediotergite with 6 long setae (only 4 in first segment) arranged as 3 pairs, sometimes with 2 or 3 small unpaired setae distributed between the pairs. One prominent seta and sometimes additional minute hairs laterad to midpoint of longitudinal branch of impression. Laterotergite I extending length of segment; 3 setae, only 1 long. Spiracles subequal; spiracular sclerite ovate, about twice as wide as spiracle and 2 to 3 times as long, situated in anterior half of segment. Pleurite well developed, subovate; decreasing in size from first to eighth segments, being only about one-half as large in eighth; with 1 large and 1 small seta. Sternum of 1 sclerite, subquadrate; impressions very faint; usually 8 to 10 unpaired setae near margins.

Ninth abdominal segment (fig. 26, *f*), exclusive of uprogomphi, slightly shorter than eighth abdominal segment and at least three-fourths as wide; four-fifths as long as wide; sides of anterior half subparallel, posterior half tapering caudally making width at anterior margin of caudal notch about three-fifths greatest width of segment. Dorsum convex, somewhat flattened posteriorly; sloping downward from front to back. Dorsal plate (*dpla*) irregularly lined and wrinkled; sometimes with a few small, shallow, indefinite pits; 4 faint longitudinal impressions, 2 laterally (*lim*) and a paramedian pair (*pim*) which converge posteriorly and meet to form a short median groove (*mg*) almost in center of dorsal plate; without setae (rarely 1 or 2 very small hairs) except at lateral margins which are slightly raised and carinate, bearing 3 prominent blunt setiferous "teeth" (*to*) (a fourth "tooth" lies farther posteriorly and more ventrally); transverse impression (*trim*) continues across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface, usually with from 10 to 14 setae on each side, but number highly variable, some issuing from small sclerotized tubercles; anteriorly on lateral aspect about a dozen conspicuous punctures. Distance between posterior margin of pleural area and anterior margin of caudal notch about one-fifth to one-fourth total length of segment (exclusive of urogomphi). Pleural area large, transversely striate except for small ovate sclerite at each anterior end. Sternum of 2 sclerites, separated anteriorly by median suture and posteriorly by tenth abdominal segment; each sclerite usually with from 5 to 8 setae, mostly in row near tenth abdominal segment.

Urogomphi (*ur*, fig. 26, *f*; fig. 26, *e*) separate, bifid; projecting caudad or dorsocaudad; prongs subequal in length. Inner prong (*ipr*) broad, much stouter than outer prong; directed caudomediad; heavily sclerotized along anteromedial margin; bearing 2 long unpaired setae, 1 on caudolateral aspect near junction with outer prong, other slightly farther ventrad. Outer prong (*opr*) subcylindrical, narrowing toward tip, which is bluntly rounded; usually slightly shorter than inner prong; projected caudodorsad, usually slightly laterad; prominent tubercle ventrolaterally at base of prong; with 2 large setae, 1 on anteromedial aspect, about halfway along prong, other arising from upper aspect of base of tubercle. Undivided part of urogomphus broad, with prominent seta ventrally near base.

Caudal notch (*cn*) small, subcircular, almost closed by converging inner prongs.

Tenth abdominal segment with whorl of 10 fine setae and usually additional smaller hairs; anal aperture linear and median.

Material used in study.—Forty-two examples, including the exuviae of five reared specimens, were examined. One larva was collected at Elkwater Lake, Alberta; the others were all collected in Saskatchewan. W. J. Brown, of Ottawa, identified the reared adults. All material is in the Canadian national collection. The following notes refer to separate collections for which there are associated reared adults.

9; Saskatoon, Saskatchewan; June 21, 1930; 3 adults emerged July 28, July 29, Aug. 1, respectively; R. Glen.

3; Cypress Hills, Saskatchewan; July 18, 1935; 2 adults emerged Aug. 4 and Aug. 8; R. Glen.

* * *

LUDIUS SJAELANDICUS (Müller)

FIGURES 14, *f*; 27

Elater sjaelandicus MÜLLER, Fauna Insectorum Friedrichsdalina, p. 21, 1764.

Elater tessellatus FABRICIUS (nec Linnaeus), Systema Eleutheratorum, p. 211, 1775.

Corymbites tessellatus (Fabricius), CANDEZE, Monographie des elatérides, vol. 4, p. 104, 1863.

Corymbites sjaelandicus (Muller), SCHIODTE, Naturh. Tidsskr., ser. 3, vol. 3, p. 554, 1865.

Corymbites (*Actenicerus*) *sjaelandicus* (Muller), SCHENKLING, Coleopt. Cat. (ed. Junk), vol. 2, pt. 88, p. 368, 1927.

Ludius sjaelandicus (Muller), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 391, 1932.

This species is well known in northern and central Europe and in Siberia. According to Leng (1920, p. 169) and Van Dyke (1932,

p. 391) *sjaelandicus* also inhabits the northeastern part of North America, but no larvae have been obtained from this region.

Larvae have been collected from rotten birch, sphagnum, and cow dung, but the typical habitat is the moist soil of low-lying land such as peat moors, alder swamps, grassy meadows, and damp, moss-covered parts of forests. Injury to domestic plants frequently results when such areas are brought under cultivation. Durnovo (1935) reports this species as a pest of vegetables on peaty soil recently cleared of alder. He further states that the larvae are much less numerous in clayey soils and practically absent from sandy areas. Pupation occurs in late July or early August.

The larva has been described from Denmark by Schiodte (1870, p. 521) and Henriksen (1911, pp. 261-262), and from Germany by Beling (1883, pp. 272-273, "*tessellatus* L."). It is readily recognized by having the spiracles situated in the posterior half of the eighth abdominal segment (*sp*, fig. 27, *d*), but not enlarged as in the *pyrrhos* group. The larva is further characterized by its bright yellow color; tridentate nasale (*n*, fig. 27, *a*); presternum of prothorax divided into 3 parts; ninth abdominal segment (fig. 27, *c*, *d*) with small caudal notch (*cn*), urogomphi (*ur*) bifid with inner prongs (*ipr*) slightly longer and much more robust than outer prongs (*opr*), 2 setae on central dorsal area, and 3 prominent blunt teeth (*to*) on lateral margins of dorsum.

Description of "mature" larva.—Length 22 mm.; greatest breadth 3.0 mm. on fourth and fifth abdominal segments. Henriksen (1911, p. 262) and Beling (1883, p. 272) record specimens measuring 26 mm. in length. Body robust; with moderately large membranes on lateral aspect; all segments broader than long; head and ninth abdominal segment about three-fourths greatest body width. Dorsum bright yellow (near "hazel" or slightly darker than "ochraceous buff," Ridgway, 1912); mandibles, nasale, talus, and prongs of urogomphi darker; venter slightly paler. Dorsum shiny; slightly rugose; with a few small and very shallow inconspicuous pits.

Head subquadrangular with arcuate sides, about as thick at base as long; flattened above and below.

Frontoclypeal region with posterior part extending backward almost to foramen magnum, truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (*n*, fig. 27, *a*) with tip tridentate when uneroded; median denticle largest, lateral denticles projecting anterolaterad. Subnasale (*sn*) consisting of strongly sclerotized transverse ridge with large, forward-projecting

median denticle; finely serrate (when uneroded) on each side of median tooth. Paranasal lobes produced beyond nasale, each bearing 3 setae (1 small).

Epicranial plates nearly smooth. Dorsal sulci shallow, each with 4 setae subequally spaced, the most anterior seta being very long; others very small, somewhat peglike. Ventral sulci bearing row of 2 to 4 setae, only 1 or 2 conspicuous. Two large unpaired latero-epicranial setae. Eye spot black, well defined, ovate or circular; bordered by 2 prominent setae. Postgenal areas expanded mesad, almost or actually meeting.

Gula (*gu*, fig. 27, *b*) short, greatly narrowed (sometimes obliterated) in the middle by converging postoccipital sutures; glabrous.

Antenna with first joint clavate, one-half to three-fifths as wide as long; without setae; 7 to 9 small pores. Second joint subcylindrical, slightly more than one-half as wide as long; two-thirds length of basal joint; 1 or 2 pores; a few minute setae borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, about one-third as long as second segment and one-quarter as wide; 4 setae on apex.

Mandible of moderate length, robust; ventrally, about two-thirds as wide at base (ventral aspect) as long; retinaculum very large; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with shallow dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and more strongly convex dorsally.

Ventral mouthparts three-fourths as wide across bases of stipites as across anterior ends of stipites. Cardines slightly separated; without seta between rami of Y-shaped brace. Stipes large, subrectangular; proxistipes and dististipes not distinct; with 2 prominent setae on antero-lateroventral aspect. Galea with basal joint subcylindrical, about as long as terminal joint, without setae or pores: terminal segment narrower than basal segment, with 4 to 6 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First joint almost as wide as long; distally on mesoventral surface with group of 3 to 5 small pores; without setae. Second segment almost twice as long as wide; longer than first segment and as wide; without setae; with 3 or 4 pores. Third segment almost as long as wide; one-half or less length of second segment; without setae; with 2 or 3 pores ventrally. Fourth segment slightly longer than wide; almost as long as third segment; without pores or setae. Postmentum with 1 long

seta at each corner. First prementum with 1 large seta just caudad to base of each palpus. Labial palpus with basal joint at least one-half length of first prementum, longer than wide, without setae, with 5 or 6 pores; terminal joint about one-half length and less than one-half width of basal segment, without setae, usually with 1 pore.

Prothorax nearly equal to combined length of mesothorax and metathorax; wider posteriorly; slightly wider than long. Tergites slightly rugose, with few small and very shallow pits; anteriorly with 2 pairs large setae (on each side of median dorsal suture) in transverse row; posteriorly with 4 prominent setae in transverse row, only 2 most medial setae paired; glabrous elsewhere. Episternum with 1 large seta. Epimeron bearing 1 small seta. Presternal area consisting of 3 sclerites as follows: A small posterior median sclerite, anteriorly attenuate; 2 large subtriangular lateral sclerites (sometimes partially fused) striate on anterolateral aspect, with 1 stout seta laterally and a diagonal row of 4 or 5 minute setae on anteromedial aspect. Eusternum small, usually with narrow medial sclerite. Sternellum and poststernellum indefinite, small, membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites with few small and very shallow pits; transverse branch of impression reaching about one-fourth distance from longitudinal branch to middorsal suture; longitudinal branch of impression short. Anterior part of each mediotergite with 1 or 2 minute setae laterad to impression. Posterior part of mediotergite with 4 conspicuous setae in transverse row, only the 2 most median setae paired. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Episternum bearing from 2 to 6 short spinelike setae. Eusternum without transverse row of setae.

Legs rather short, strong. Coxa with up to 25 spinelike setae on anterior aspect, mostly in 2 oblique rows diverging mesally with conspicuous glabrous area between rows; 7 to 8 stout setae on posterior surface. Trochanter with 10 to 12 spinelike setae on medioanterior surface, arranged in 2 rows; 6 to 9 such setae and 1 fine seta scattered on posterior surface; 2 well-developed setae on medial aspect. Femur usually with 9 to 11 spinelike setae on medioanterior surface; 4 to 6 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 fine setae on lateral surface. Tibiotarsus about as long as femur, but narrower; with 5 or 6 setae around distal margin; 4 spinelike setae and 1 slender seta on medioanterior surface; 3 or 4 spinelike setae on posterior surface. Ungula, when uneroded, almost as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; fourth to sixth segments widest. Mediotergites (*mtg*, fig. 27, *d*) with few small, shallow pits; transverse branch of impression (*trim*) shallow, slightly sinuate, on second to eighth segments reaching from one-half to three-fourths distance from longitudinal branch to mid-dorsal suture, shorter on first segment; longitudinal branch of impression shallow, variable in length, extending from one-half to nearly total distance from transverse branch to posterior transverse row of setae. Anterior part of mediotergite without setae. Posteriorly on each mediotergite, transverse row of 5 setae on second to eighth segments, only the most lateral seta being unpaired; only 3 setae in posterior row on the first abdominal segment. Usually 1 small seta, rarely 2, along margin of mediotergite laterad to impression. Spiracles (*sp*, fig. 27, *d*) subequal in size, in anterior half of segment except in eighth abdominal segment where spiracle always in posterior half. Spiracular sclerite (*spsc*) well developed, subovate; usually wider than spiracle and 2 to 3 times as long as spiracle, increasing in size from first to seventh segment, smaller in eighth segment. Laterotergite I (*ltg I*) extending length of segment; 1 large seta on dorsal margin. Pleurite large, subovate, with 1 large seta. Sternum of 1 piece, subquadrate; 4 faint impressions, indefinite except on the more anterior segments; with 1 stout seta at each corner.

Ninth abdominal segment (fig. 27, *c*, *d*), exclusive of urogomphi, about as long as eighth abdominal segment and three-fourths as wide; almost as long as wide; sides of anterior half subparallel, posterior half tapering caudally making width at anterior margin of caudal notch two-thirds (or less) greatest width of segment. Dorsum convex, more pronounced anteriorly. Dorsal plate (*dpla*) sloping downward from front to back, usually with a short transverse concavity slightly caudad to the 2 setae found near the middle of the plate; irregularly lined and wrinkled, but without pits; 4 faint longitudinal impressions, 2 laterally (*lim*) and a short paramedian pair (*pim*) in anterior part of plate; lateral margins slightly raised and carinate, bearing 3 prominent blunt "teeth" (*to*), each with a long bristle; transverse impression (*trim*) feeble, usually interrupted in middle. Tergite (*tg*) continues uninterruptedly laterally and on posterior ventral surface; usually with from 5 to 10 unpaired setae on each side, some issuing from small sclerotized tubercles. Distance between posterior margin of pleural area (*pl*) and anterior margin of caudal notch from one-sixth to one-fifth of total length of segment (exclusive of urogomphi). Pleural area well developed, membranous, transversely striate. Ster-

num of 2 sclerites, separated anteriorly by median longitudinal suture, and posteriorly by tenth abdominal segment; each sclerite with 2 or 3 setae in row around tenth abdominal segment.

Urogomphi (*ur*, fig. 27, *c*, *d*) separate, robust, bifid; inner prong slightly longer and much more robust than outer prong. Inner prongs (*ipr*) short, stout, with hard, dark anteromedian margins; directed inwardly; tips bluntly pointed, frequently meeting or overlapping; each with 2 stout setae, 1 issuing from base of small tubercle on caudolateral margin and 1 from midventral surface. Outer prongs (*opr*) shorter and more slender than inner prongs, projecting upward, sometimes slightly outward and backward; each terminating in horny tip, sometimes with short, sharp point inclined inward; 2 large setae, 1 on anteromedial surface of distal half of prong, the other at base of prong on lateroventral aspect. Undivided part of urogomphus short and very broad, with 1 stout seta ventrally just anterad to bases of prongs.

Caudal notch (*cn*) small, subovate or shield-shaped, slightly longer than wide; very narrow posteriorly, often entirely closed by converging inner prongs.

Tenth abdominal segment (*10*) surrounded by 10 prominent setae; anal aperture linear and median.

Material used in study.—Fourteen larvae were examined. These were collected from Denmark (6), Finland (5), and Germany (3). So far as is known, none of these specimens were collected at the same time and place as specimens that subsequently were reared, but the larva of this species has been known to European workers for many years and it is believed that the material is reliably named. The material examined is deposited in the Canadian national collection, the U. S. National Museum, and van Emden's collection.

THE LUDIUS PYRRHOS GROUP

FIGURES 11, *e*; 28

KEY TO SPECIES

From eastern North America....................**pyrrhos** (Herbst) (p. 148)
From western North America................**protractus** (LeConte) (p. 149)

Knowledge of this group is limited to rather inadequate larval material of *pyrrhos* (Herbst) and *protractus* (LeConte). The group differs from all other known *Ludius* larvae in the character of the spiracles of the eighth abdominal segment (figs. 11, *e*; 28, *a*), which

are at least twice as long as the spiracles in the other abdominal segments and situated much farther caudad. Other important diagnostic features are found in the nasale (fig. 28, *c*), which is tridentate at tip with small median denticle, and in the mandible (fig. 28, *b*) with its unusually robust distal half. The group is not closely allied to any other of the known *Ludius* larvae.

Larvae of the *pyrrhos* group are yellowish brown, exceeding 20 mm. in length when full-grown. Dorsum punctulate. Caudal notch small, almost closed posteriorly. Urogomphi bifid, prongs subequal in length; inner prong broad; outer prong less robust, terminating in moderately blunt point. Dorsum of ninth abdominal segment (fig. 28, *d*) with 2 unpaired setae, and sometimes with faint short median groove; anterior margin of dorsal plate well defined throughout; 3 rounded "teeth" (*to*), sometimes with pointed tips, on lateral margins of dorsum. On ninth abdominal segment the distance between the pleural area and caudal notch equals one-quarter to one-third of entire length of segment, exclusive of urogomphi. Frontoclypeal area truncate posteriorly. One "sensory" appendix on second segment of antenna. Second joint of maxillary palpus longer than first joint. Eyes present, 2 prominent unpaired setae around each eye. Epicranial plates each with 2 prominent unpaired lateroepicranial setae. Gula short and very narrow. Presternum of prothorax of 1 piece, but deeply incised on lateroposterior aspects, almost resulting in a separate small median piece posteriorly. Without spinelike setae on episterna of mesothorax and metathorax. Mediotergites of mesothorax and metathorax with definite impressions. Mediotergites of abdominal segments (*mtg*, fig. 28, *a*) with transverse branches of impressions (*trim*) failing to reach middorsal suture and with a posterior transverse row of 5 prominent setae arranged as 2 pairs with 1 unpaired hair farther laterad.

LUDIUS PYRRHOS (Herbst)

FIGURES 11, *e*; 28

Elater pyrrhos HERBST, Natursyst. Ins. Kafer, vol. 10, p. 30, 1806.
Corymbites pyrrhos (Herbst), LECONTE, Trans. Amer. Philos. Soc., new ser., vol. 10, p. 447, 1853.
Ludius pyrrhos (Herbst), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 394, 1932.

The larval material of this species that was available for study was not adequate for a description of greater detail than that given under the *pyrrhos* group.

The third segment of the antenna is very short, apparently being less than one-half as long as the second segment. This might be a specific character. At present, the separation of the larvae of *pyrrhos* and *protractus* is best made on the basis of geographical distribution.

Apparently the material examined was part of a collection made in a cornfield that was damaged by wireworms. This is the only information available on the biology of the species.

Material used in study.—According to the ledger records of wireworm rearing at the United States Bureau of Entomology Laboratory, Hagerstown, Md., specimens given the accession numbers 6066 to 6080, inclusive, were collected together at College Park, Md., April 24, 1916, and were identified, probably by J. A. Hyslop, as *Ludius pyrrhos* (Herbst). Larval exuviae of 3 specimens, labeled 6066, 6067, and 6069, and a much desiccated whole larva, labeled 6075, were found and examined. The notes indicate that specimen No. 6068 was reared, and an adult of *Ludius pyrrhos* (Herbst) bearing this number has been reported by M. C. Lane to be in the collection at the Wireworm Laboratory, Walla Walla, Wash. Mr. Lane confirmed the identification of this adult. Unfortunately, the larval exuvium of No. 6068 was not available, but the evidence strongly suggests that the material that was examined was of this species. The larval material is now in the U. S. National Museum.

LUDIUS PROTRACTUS (LeConte)

Corymbites protractus LECONTE, Proc. Acad. Nat. Sci. Philadelphia, p. 85, 1859.

Ludius protractus (LeConte), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 410, 1932.

Van Dyke (1932, pp. 392, 410) states that this species is widely distributed along the Pacific coast from British Columbia to northern California, and that it is a meadowland species. This suggests that the larva lives in the soil. The specimen examined was found as a pupa on June 19, which indicates a rather early seasonal development.

Additional larval material is necessary before a complete detailed description can be given and before reliable structural characters are known for the separation of *protractus* and *pyrrhos*.

Material used in study.—Only the larval exuvium of a reared specimen was available for examination. W. J. Brown, of Ottawa, confirmed the identification of the reared adult.

1; Towle District, Placer County, Calif.; June 19, 1932; collected as a pupa which emerged immediately; H. H. Keifer. (U.S.N.M.)

* * *

THE LUDIUS LIMONIIFORMIS GROUP

FIGURES 11, *h*; 29

KEY TO SPECIES

With 5 or more "teeth" laterally on dorsum of ninth abdominal segment (*to*, fig. 29, *b*); larva rarely exceeding 20 mm. in length; west of Lake Superior .... **limoniiformis** (Horn) (?) (p. 151)

With 4 "teeth" laterally on dorsum of ninth abdominal segment (*to*, fig. 29, *e*); larva might exceed 30 mm. in length; eastern North America.... .... **cylindriformis** (Herbst) (?) (p. 156)

This group is represented in the larval stage by two species that are not positively identified, but which are believed to be *limoniiformis* (Horn) and *cylindriformis* (Herbst).

These larvae are soil inhabiting, apparently preferring relatively moist situations. Both species are minor pests of cultivated plants.

Ludius limoniiformis and *L. cylindriformis* larvae are easily separated and might eventually be placed in different species groups, but they possess many characters in common and are not closely allied to any other of the known *Ludius* larvae. The body is relatively long and narrow, most of the abdominal segments being as long as wide. Eyes are absent and the presternum of prothorax is undivided. Other important characters are found in the urogomphi (fig. 29, *b*-*e*), the dorsum of the ninth abdominal segment (fig. 29, *b*, *e*)—especially the sharp marginal "teeth" (*to*) and the lack of a mediodorsal groove—and the nasale (fig. 29, *a*).

The larvae of the *limoniiformis* group are light brown or yellow brown. Caudal notch small, subcircular or subovate, nearly closed posteriorly. Urogomphi bifid; inner prong broad, with 1 or more tubercles on posterior aspect; tip of outer prong sharp, inclined inward or forward. Ninth abdominal segment (fig. 29, *b*, *e*) with 4 or more prominent, sharp "teeth" (*to*) on lateral aspects of dorsum and with 4 unpaired setae on the central dorsal area, but without a median longitudinal groove. Nasale (fig. 29, *a*) with tridentate tip, lateral denticles small and frequently eroded off. Frontoclypeal area truncate posteriorly. Second joint of antenna bearing 1 "sensory" appendix. Basal joint of labial palpus without setae. Eyes absent. Gula short, narrow. Presternum of prothorax undivided. Episterna of mesothorax and metathorax with several spinelike setae. Abdominal mediotergites with some of prominent setae paired (usually 2 pairs) or in a semipaired arrangement, and in second to fifth segments with transverse branches of impressions reaching to or nearly to the mid-dorsal suture. First 8 abdominal segments with small pleurites,

becoming narrower in more posterior segments; sternum undivided; and spiracles in anterior half of each segment.

LUDIUS LIMONIIFORMIS (Horn) (?)

FIGURES 11, *h*; 29, *a-c*

Corymbites limoniiformis HORN, Trans. Amer. Ent. Soc., vol. 3, p. 320, 1871.
Ludius limoniiformis (Horn), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 420, 1932.

According to Van Dyke (1932, pp. 396, 420) this species "seems to be rather widely spread in the country to the west of the Great Lakes," and apparently extending into Alberta.

The larvae are known from the parklands of Saskatchewan, where they are found most frequently in association with the grassy margins of snowberry (*Symphoricarpos*) and silverberry (*Elaeagnus*) thickets. The species persists for many years after such areas are brought under cultivation. King (1928, p. 705) refers to *L. limoniiformis* as a crop pest of minor importance in Saskatchewan.

This larva resembles the more eastern *cylindriformis* (Herbst) but is smaller, and has more "teeth" on the margins of the dorsum of the ninth abdominal segment (fig. 29, *b*).

Description of "mature" larva.—Length 16.5 mm.; greatest breadth 2.0 mm.; thoracic and abdominal segments subequal in width with prothorax sometimes widest segment. Fully distended larva measured 22 mm. Body only moderately robust; with moderate-sized membranous areas on lateral aspect; most segments of abdomen as long as wide; head and ninth abdominal segment about five-sixths greatest body width. Dorsum light brown to yellowish brown (near "clay color," Ridgway, 1912); head and prothorax distinctly darker; venter slightly paler. Dorsum slightly rugose, more pronounced rugosity on abdomen; with sparse small punctures, more abundant on more posterior segments.

Head subquadrangular with arcuate sides; flattened above and below.

Frontoclypeal region with posterior part extending backward almost to foramen magnum; truncate posteriorly. Two prominent anterior nasosulcal setae on each side of base of nasale. Nasale (*n*, fig. 29, *a*) a well-developed tooth terminating tridentate when uneroded; median denticle large, small lateral denticles frequently eroded giving appearance of unidentate tip. Subnasale (*sn*) consists of many fine, short, sharp, forward-projecting denticles; frequently eroded. Paranasal

lobes produced beyond nasale; each bearing 3 setae, 1 very small and sometimes lacking.

Epicranial plates smooth, or with few small pits. Dorsal sulci shallow; each with 5 setae subequally spaced, most anterior seta long, others small. Ventral sulci bearing row of 5 to 8 setae, usually only 2 or 3 conspicuous. Two large, unpaired, lateroepicranial setae. Eye spot absent; normal eye region bordered by 2 unpaired setae. Postgenal areas expanded mesally, almost meeting; glabrous.

Gula short, narrow; goblet-shaped; constricted posteriorly by converging postoccipital sutures; glabrous.

Antenna with first joint weakly clavate; almost two-thirds as wide as long; without setae; 3 or 4 small pores. Second segment subcylindrical, about two-thirds as wide as long; three-fifths length of basal joint; 1 or 2 pores; a few small setae or pegs borne distally; 1 medium-sized conical "sensory" appendix just ventrad to base of third joint. Terminal segment small, about one-half as long as second segment and one-quarter as wide; 4 setae and 2 or 3 "sensory" pegs on apex.

Mandibles of moderate length, robust; about two-thirds as wide at base (ventral aspect) as long; retinaculum well developed; penicillus sometimes reaching base of retinaculum. Distal half inward bending; pointed; outer surface convex with short dorsal groove; inner face slightly excavate with small median carina, ventral margin of inner face sharp and slightly convex ventrally, dorsal margin sharp and moderately convex dorsally.

Ventral mouthparts about four-fifths as wide across bases of stipites as at anterior ends of stipites. Cardines slightly separated. Stipes large, subrectangular; proxistipes and dististipes not distinct; usually 4 or 5 prominent setae on antero-lateroventral aspect. Galea with basal joint slightly longer and one-half wider than terminal segment, without setae or pores; terminal joint curved, lateral surface longer than inner surface, 2 or 3 pores on lateroventral aspect. Maxillary palpi with all segments subcylindrical. First joint slightly longer than wide; distally on mesoventral aspect with group of about 6 small pores and 2 setae. Second segment as wide as basal joint and longer; without setae; 3 or 4 pores. Third segment about as wide as long; about one-half length of second joint; 2 pores ventrally; distally with 1 minute seta on mesoventral aspect and 1 near lateral aspect. Fourth joint longer than wide; nearly as long as third joint; sometimes 1 minute seta on medial aspect; 1 pore on lateral surface. Postmentum with 1 long seta near each corner. First prementum

with 1 large seta just caudad to base of each palpus. Labial palpus with basal joint cylindrical, about one-half length of first prementum, about as long as wide, without setae, 3 or 4 pores; terminal joint shorter than basal joint and about one-half as wide, without setae, 1 or 2 pores.

Prothorax about equal to combined length of mesothorax and metathorax; wider posteriorly; about as long as wide. Tergites minutely punctulate; anteriorly with 5 setae (on each side of median dorsal suture) in transverse row, arranged as 2 pairs with 1 unpaired seta between, the unpaired hair often found near the more lateral pair giving appearance of group of 3 setae; posteriorly with 4 setae in transverse row, arranged as 1 pair with 2 unpaired setae farther laterad; glabrous elsewhere. Episternum with 1 large and usually 2 smaller setae. Epimeron bearing 1 small seta. Presternal area consisting of 1 large triangular sclerite, posteriorly acute, striate on anterolateral aspects, 1 prominent seta near each lateral margin, and 2 short diagonal rows each of 4 minute setae anteriorly near middle. Eusternum small, membranous, with small narrow median sclerite. Sternellum and poststernellum indefinite, small and largely membranous.

Mesothorax and metathorax each about twice as wide as long. Mediotergites sparsely punctulate; transverse branch of impression variable in length, commonly extending about one-fourth distance from longitudinal branch to middorsal suture; longitudinal branch of impression very short or absent. Anterior part of each mediotergite sometimes with several minute setae issuing from punctures; 2 or 3 small setae arranged as follows: 1 just behind transverse branch of impression, 1 just laterad to impression, and sometimes 1 near medial end of impression or slightly farther mediad. Posterior part of each mediotergite with transverse row of 4 conspicuous setae, the 2 most medial paired; sometimes 1 minute seta just caudad to the most lateral of the large hairs. Anterior laterotergite subtriangular, one-half as large as subovate posterior laterotergite. Episternum bearing up to 10 spinelike setae, usually 6 to 8. Mesothoracic spiracle subequal in size to spiracles in abdomen.

Legs subequal in length. Coxa of prothoracic leg usually with from 25 to 32 spinelike setae on anterior surface, mesothoracic and metathoracic legs with from 20 to 27 such setae; 6 to 8 stout setae and a few finer hairs on posterior aspect. Trochanter with 5 to 8 spinelike setae on medioanterior surface; 5 to 7 such setae and 1 fine seta on posterior surface; 2 long setae on medial aspect. Femur

usually with 5 to 7 spinelike setae on medioanterior surface; 2 or 3 spinelike setae and 1 slender seta on posterior surface; 1 long seta on medial aspect; 1 or 2 minute setae on lateral surface. Tibiotarsus with 6 setae around distal margin; 2 or 3 spinelike setae on medioanterior surface; 2 or 3 spinelike setae on posterior face. Ungula, when uneroded, almost as long as tibiotarsus.

First to eighth abdominal segments subequal; first segment shortest; seventh and eighth segments very slightly narrower. Mediotergites somewhat rugose and with small shallow punctures, rugosity and punctation becoming stronger from first to eighth segments; transverse branches of impressions sinuate, reaching to or nearly to middorsal suture on second to fifth segments, sometimes nearly as long on sixth segment, shorter on other segments especially first and eighth; longitudinal branch of impression extending approximately one-half distance from transverse branch to posterior transverse row of setae. Anterior part of each mediotergite usually with 4 setae, 2 (rarely 3) lying within transverse branch of impression, 1 toward middle of sclerite, equidistant from branches of impression, and 1 laterad to impression. Posterior part of each mediotergite with 5 large setae arranged as 2 pairs (sometimes only semipaired) and 1 unpaired seta farther laterad; sometimes 1 minute seta near unpaired large hair; sometimes, especially on more posterior segments, up to 5 additional small setae, usually slightly posterior to row of larger setae. Laterotergite I extending length of segment; with 1 large seta. Spiracles subequal; in extreme posterior end of spiracular sclerite, which is small, subovate, about twice length of spiracle and situated in anterior half of each segment. Pleurite small, becoming narrower in more posterior segments; with 1 prominent seta and sometimes 1 or 2 minute hairs. Sternum of 1 piece, subquadrate; without definite impressions or sutures, but with a few small shallow pits; bearing 1 prominent seta near each corner and usually a few minute setae along lateral margins.

Ninth abdominal segment (fig. 29, *b*), exclusive of urogomphi, slightly shorter than eighth abdominal segment and almost as wide; as long as wide; sides of anterior half subparallel, posterior half tapering caudally making width at anterior margin of caudal notch about three-fifths to two-thirds greatest width of segment. Dorsum flat to slightly convex, sloping downward from front to back. Dorsal plate (*dpla*) roughened by irregular lines, wrinkles, and a few scattered pits; 4 faint longitudinal impressions, 2 laterally (*lim*) and a paramedial pair (*pim*) which converge posteriorly but do not meet;

2 prominent fine setae anteriorly and 2 smaller setae farther caudad; lateral margins slightly raised and carinate, typically with 5 prominent, sharp, setiferous "teeth" (*to*), sometimes with smaller "teeth" between larger ones, as many as 8 or 9 "teeth" on each side in some specimens; transverse impression (*trim*) continues across segment. Tergite continues uninterruptedly laterally and on posterior ventral surface; usually with from 20 to 35 setae on each side, many issuing from small sclerotized tubercles; anteriorly on lateral aspect with a few pits. Distance between posterior margin of pleural area and anterior margin of caudal notch approximates one-fourth total length of segment (exclusive of urogomphi). Pleural area large, transversely striate with small ovate sclerite near anterior ends. Sternum of 2 sclerites, separated anteriorly by faint median suture and posteriorly by tenth abdominal segment; each sclerite with from 5 to 10 setae, mostly in irregular row adjacent to tenth abdominal segment.

Urogomphi (*ur*, fig. 29, *b*; fig. 29, *c*) separate, bifid; projecting dorsocaudad; prongs subequal in length, but differing in shape. Inner prong (*ipr*) robust, subquadrate (rarely subtriangular), projecting caudomediad; anteromedial margin strongly sclerotized, dark; with 1 or 2 setiferous tubercles (*tub*) on caudolateral aspect, another seta just ventrad to tubercles and usually a few minute setae scattered over caudal aspect. Outer prong (*opr*) less robust, corniform, projecting caudad or dorsocaudad, sometimes slightly laterad; terminating in sharp horny point usually curving slightly forward or inward; with a prominent setiferous tubercle situated caudolaterally near base of prong; 1 prominent seta on inner aspect, about halfway up prong, 1 smaller seta on posteromedial surface and 1 minute seta medially near base of prong. Undivided part of urogomphus short, broad; usually with 1 very short, fine seta near midventral aspect. Caudal notch (*cn*) small, subcircular, almost closed by incurving inner prongs.

Tenth abdominal segment with whorl of 10 fine setae, sometimes a few additional minute setae; anal aperture linear and median.

Material used in study.—Twenty-one larvae, all from Saskatoon, Saskatchewan, were examined. This species has not been reared, and identification is based upon field association of larvae and adults. However, misidentification is unlikely because nearly all other elaterid larval types occurring in fields at Saskatoon have been identified through rearing. The material examined is deposited in the Canadian national collection.

LUDIUS CYLINDRIFORMIS (Herbst) (?)

FIGURE 29, *d, e*

Elater cylindriformis HERBST, Natursyst. Ins. Kafer, vol. 10, p. 93. 1806.
Corymbites cylindriformis (Herbst), GERMAR, Zeitschr. fur die Ent., vol. 4, p. 64, 1843.
Ludius cylindriformis (Herbst), VAN DYKE, Proc. California Acad. Sci., vol. 20, p. 399, 1932.

This species is known from the eastern provinces of Canada and from the northeastern United States and at least as far west as Indiana, where Blatchley (1910, p. 765) reports its occurrence as "frequent."

The larvae have been taken from cornfields and gardens, and Hyslop (1915a, p. 9) reports the adults as being abundant in alfalfa and wheat fields. Hawkins (1936, pp. 55-56) implies that the species is a minor crop pest in Maine, but a predaceous tendency is suggested from the observations of Devereux (1878, p. 143), who found a larva crushing the elytron of a living *Harpalus pennsylvanicus*. A hibernating larva was found on December 15 at a depth of 1 foot in a cornfield.[12]

No adequate description of the larva has been published, but Hawkins (1936, p. 59, fig. A) figured the ninth abdominal segment. Distinction from the larva of *limoniiformis* (Horn) is made primarily through greater size, characters of the ninth abdominal segment (fig. 29, *e*), and the mandibles.

The largest larva examined was not fully distended, but measured 30 mm. in length and 2.6 mm. in breadth. The mandibles are distinguished as follows: Beginning at the distal end of the antennal fossa, a shallow groove extends one-third to one-half the distance toward the tip of the mandible. The ninth abdominal segment (fig. 29, *e*) bears only 4 sharp "teeth" on each lateral margin of the dorsum; distance between pleural area and caudal notch approximates one-fifth to one-sixth total length of segment, exclusive of urogomphi; lateral and ventral aspects of tergite with fewer setae than *limoniiformis*, usually less than 20 setae on each side. The larvae examined possessed a few transverse rugae or pits on the abdominal mediotergites, especially within the angle of the impressions.

Material used in study.—Five larvae were examined, four from Springhill, New Brunswick, and one from Riverton, N. J. The species has not been reared, but the material examined appears to be similar to the larva described by Hawkins (1936) as *L. cylindri-*

[12] This observation was made at Riverton, N. J., by C. A. Thomas, of Kennett Square, Pa., and the larva was identified by the writer.

formis. Specimens examined are deposited in the Canadian national collection and the Pennsylvania Agricultural Experiment Station collection.

Genus LIMONIUS Eschscholtz

FIGURES 9, *g*; 10, *e*; 11, *a*, *d*, *g*; 30-32

In the present study, the name *Limonius* Eschscholtz is used in the broad sense, including all species that have been placed in *Phelctes* Kiesenwetter and *Nothodes* LeConte. The larval morphology suggests this procedure to be best for the present at least. Hyslop (1921) has shown *Pheletes* to be isogenotypic with *Limonius*, and Van Dyke (1932, p. 333) suppresses the name *Nothodes*, placing its lone species, *dubitans* LeConte, in *Limonius*.

Accurate specific identification of the larvae of this genus is made doubly difficult because of the apparent unsettled status of the taxonomy of the adults. A thorough revision of the genus would greatly assist in naming the larvae.

Larvae of 14 species of *Limonius* have been studied, 12 from North America and 2 from Europe.

Dr. Van Dyke (1932, pp. 333, 360) states that with one exception the genus is holarctic in distribution and shows a preference for valleys and more open places. The great majority of the larvae studied are soil inhabiting and in North America are important pests in fields and gardens. Only one species, unidentified, is known to occur in decaying wood, but a few prefer moist forest litter.

On the basis of rather scanty information it appears that pupation occurs most commonly in July or early August. The newly developed adults pass the winter in their pupal chambers.

Limonius is part of that large, complex group whose larvae possess an undivided prosternum (*prst*, fig. 31, *c*), have impressions on the mediotergites of mesothorax and metathorax, and with one exception, *L. pilosus* (Leske), have the nasale tridentate at the tip. On the basis of larval characters the closest allies appear to be *Elathous bicolor* (LeConte), *Ludius resplendens* (Eschscholtz), and species of the *Ludius limoniiformis* group.

Generic separation is greatly facilitated if *Limonius* larvae are considered in two artificial groups: *Group I*, caudal notch small; outer urogomphal prongs reduced to the size of small tubercles (figs. 30, *d*, *f*; 31, *d*, *e*). *Group II*, caudal notch small; outer urogomphal prongs at least moderately well developed (figs. 30, *h*; 31, *f*; 32, *d*, *e*), sometimes as long as inner prongs; and ninth abdominal segment (figs. 30, *h*; 32, *d*) without a mediodorsal groove and with well-rounded "teeth" (*to*) on lateral aspects of dorsum. *Group I* is

distinct from all other known larvae in this complex of related genera. *Group II* is separated from *Elathous bicolor* and *Ludius resplendens* through the absence of the mediodorsal groove on the ninth abdominal segment, and from larvae of the *Ludius limoniiformis* group by the blunt "teeth" on the same segment.

Limonius larvae may be characterized as follows: Dorsum pale yellow (or orange-yellow) to yellow-brown, with minute (inconspicuous) to moderate-sized punctures, but lacking prominent transverse rugae. Caudal notch small. Urogomphi bifid, prongs subequal or outer prongs shorter than inner prongs. Ninth abdominal segment usually without a mediodorsal groove, and without "teeth" or with well-rounded "teeth" on lateral margins of dorsum. Nasale variable, but usually tridentate at tip. Frontoclypeal area truncate or broadly rounded posteriorly. Eyes present or absent, with 2 to 4 setae around eye region. Usually 2 unpaired lateroepicranial setae on each gena. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandibles variable (figs. 30, *c, e;* 32, *b*). Presternum of prothorax (fig. 31, *c*) undivided. Mesothorax and metathorax with impressions on mediotergites. Abdominal mediotergites with impressions of varying length; and usually with 5 to 7 prominent setae in posterior transverse row, definitely arranged as 2 or 3 pairs in nearly all species.

KEY TO "SPECIES GROUPS" AND ISOLATED SPECIES OF LIMONIUS

1. Outer prongs of urogomphi reduced to the size of small tubercles (*opr,* figs. 30, *d, f;* 31, *d, e*) 2
   Outer prongs of urogomphi pronglike (*opr,* figs. 30, *h;* 31, *f;* 32, *d, e*) .. 5
2. Ninth abdominal segment with 2 conspicuous conical protuberances (*pro,* fig. 31, *e, g*) .... **pectoralis** LeConte (p. 161)
   Ninth abdominal segment without such protuberances 3
3. Mandible (fig. 30, *c*) with prominent toothlike expansions anterior to retinaculum; nasale (*n,* fig. 30, *a, b*) short, with 3 subequal teeth.... .... the **aeneoniger** group (p. 159)
   Mandible without toothlike expansions anterior to retinaculum.......... 4
4. Eyes absent; ninth abdominal segment without a definite mediodorsal groove; each paranasal lobe with a cluster of 12 or more "sensory" pores (*pulp,* fig. 32, *a*) .... **aeger** LeConte (p. 163)
   Eyes present; ninth abdominal segment with a mediodorsal groove; paranasal lobes without definite cluster of pores..................... .... unidentified, possibly **confusus** LeConte (p. 162)
5. Nasale (*n,* fig. 30, *g*) of 1 pointed tooth; mandible (fig. 30, *e*) with very large retinaculum and expanded medioventral cutting edge; European .... **pilosus** (Leske) (?) (p. 160)
   Nasale (*n,* figs. 31, *b;* 32, *a*) with tip tridentate; mandible (fig. 32, *b*) without above characteristics; North American..the **canus** group (p. 164)

THE LIMONIUS AENEONIGER GROUP

FIGURES 9, *g*; 11, *a*; 30, *a-d*, *f*

Only two species are included in this group, one from Europe, the other from western North America. The larva of the genotype, *Limonius aeneoniger* (DeGeer) (= *Pheletes Bructeri* Panzer), is recorded by Beling (1884, p. 205) from earth in dry, sunny places in European forests, preferably under moss. H. P. Lanchester, of Walla Walla, Wash., collected larvae of the Pacific coast species, *L. consimilis* Walker, "in moss on boulders in shade."

This strongly characterized group is distinguished as follows: Mandible (fig. 30, *c*, probably considerably eroded) with prominent toothlike expansions anterad to retinaculum; nasale (*n*, fig. 30, *a*, *b*) short, with 3 subequal teeth; subnasale (*sn*) with 1 prominent obtuse tooth; and abdominal mediotergites with transverse branches of impressions short, extending less than one-half distance from longitudinal branches to middorsal suture.

Preserved larvae are yellow to yellow-brown in color, with head and prothorax darker, but living specimens appear to differ since Beling (1884, p. 205) reports "larva intense yellow-red" and Lanchester (1941, p. 368) records *consimilis* as "orange-yellow" when collected. Both are relatively small species, *aeneoniger* attaining 9 mm. in length, and the largest *consimilis* examined measuring 13 mm.

Urgomphi (*ur*, fig. 30, *f*; fig. 30, *d*) with outer prongs (*opr*) very small. Ninth abdominal segment (fig. 30, *f*) without mediodorsal groove (sometimes with a shallow, central, subcircular depression); without setae on central dorsal area; "teeth" (*to*) very small, practically wanting, on lateral aspects of dorsum; and distance between caudal notch and pleural area about one-fifth length of segment, exclusive of urogomphi. Frontoclypeal area (fig. 30, *a*) truncate or broadly rounded posteriorly. Paranasal lobes (*pnl*) without definite pore cluster. Eyes present. Two prominent unpaired lateroepicranial setae on each gena. Without setae on ventral aspect of basal segment of labial palpus. Mesothorax and metathorax without spinelike setae on episterna (usually 1 fine seta on each episternum). Abdominal mediotergites finely punctured and each with 2 or 3 pairs of setae in posterior transverse row.

Material used in study.—*L. aeneoniger* (DeGeer): Only 2 specimens were available for examination, 1 from Norway, the other from Denmark. As far as is known, neither of these was associated

with reared material. Specimens deposited in the U. S. National Museum.

L. consimilis Walker: Nineteen specimens collected at Asotin, Wash., were examined. These were received through the courtesy of M. C. Lane and H. P. Lanchester, of Walla Walla, Wash. Mr. Lanchester reared larvae from the same collection. The reared adults were identified by M. C. Lane and placed in the collection of the Wireworm Laboratory at Walla Walla. Larvae examined are deposited in the Canadian national collection.

LIMONIUS PILOSUS (Leske) (?)

FIGURE 30, *e, g, h*

The larva of this European species has been described by Beling (1883, p. 302; 1884, p. 205), Rey (1887), and Henriksen (1911, pp. 255-256) under the name of *nigripes* Gyllenhal. In the present study examination has been confined to one larva from Amager Falled, Denmark, that is believed to be identical with that described by these authors. This specimen is deposited in the U. S. National Museum.

According to Beling and Henriksen, the larva inhabits the soil, chiefly in meadowland.

This larva differs from all other *Limonius* larvae known to the writer, as follows: Nasale (*n*, fig. 30, *g*) unidentate, sharply pointed when uneroded; subnasale (*sn*) consisting of a transverse ridge bearing about 8 subequal forward-projecting denticles; and mandible (fig. 30, *e*) with greatly enlarged retinaculum (*ret*) and expanded ventral cutting edge. Rey (1887) states that the larva of *Limonius cylindricus* Paykull is very similar.

Length 14.5 mm., as recorded by Henriksen and Beling. Outer prongs of urogomphi (*opr*, fig. 30, *h*) shorter than inner prongs (*ipr*), but definitely pronglike. Dorsum of ninth abdominal segment (fig. 30, *h*) apparently without a median sulcus, without setae on central area, and with small, blunt "teeth" (*to*) on lateral aspects. Frontoclypeal area truncate posteriorly. Eyes present. Two unpaired lateroepicranial setae on each gena. Five or six spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites with small punctures, prominent setae arranged in definite pairs, and with transverse branches of impressions extending about four-fifths of distance from longitudinal branches to middorsal suture.

LIMONIUS PECTORALIS LeConte

FIGURE 31, *a, e, g*

This northern species is known from Alaska and from coast to coast in Canada. Larvae have been reared from Cleeves, Saskatchewan.

This species is of considerable economic importance in the parklands of northern Saskatchewan and the Peace River Block of Alberta and British Columbia. As reported by King (1928, p. 704), *pectoralis* appears to be definitely associated with deep, rich, loam soils, and somewhat low-lying situations, and under native conditions prefers the grassy margins of snowberry (*Symphoricarpos*) thickets.

After a lengthy period of drought larvae were found on June 30 as deep as 19 inches in an old bromegrass field. However, it would appear that pupation occurs much nearer the soil surface, since overwintering adults have been taken at depths between 2 and 4 inches. Rearing records indicate that pupation occurs in late summer or early autumn, but the exact time is not known.

The larva of *pectoralis* differs from other known elaterids in having 2 prominent conical protuberances on the dorsum of the ninth abdominal segment (*pro,* fig. 31, *e, g*). The nasale (fig. 31, *a*) is also characteristic, the median denticle being smaller than the lateral denticles.

The largest larvae examined measured 14 mm. Outer prongs of urogomphi (*opr,* fig. 31, *e, g*) are reduced to mere, pointed tubercles. Ninth abdominal segment without a mediodorsal sulcus, without "teeth" (rarely 1 or 2 minute swellings) on lateral aspects of dorsum, and distance between caudal notch and pleural area approximates one-eighth to one-sixth length of segment, exclusive of urogomphi. Frontoclypeal area truncate posteriorly. Eyes absent. Two unpaired lateroepicranial setae on each gena. Mandible of common lepturoidine type, with well-developed retinaculum. One small seta on ventral surface of basal segment of labial palpus. Mesothorax and metathorax with impressions indistinct on mediotergites, and with 4 to 6 spinelike setae on each episternum. Abdominal mediotergites with impressions reaching the middorsal suture on second to eighth segments, with fine, scattered punctures, and with 3 pairs of setae in posterior transverse row.

Material used in study.—Fifteen examples were examined, including the larval exuviae of two reared specimens. All the material was from the parklands of Saskatchewan except 7 larvae from Fairbanks, Alaska. The following notes pertain to the reared material:

2; Cleeves, Saskatchewan; (no date); both reared to adults by Nov. 15, 1926; K. M. King. (C. N. C.)

LIMONIUS CONFUSUS LeConte (?)

A few larvae of this species have been collected at Urbana and Danville, Ill., and at Arnprior, Ontario. This is a typical forest species, the larvae occurring in decaying wood and in moist, well-decayed leaf litter.

The identity of these larvae is unknown, but it is most likely to be either *L. confusus* LeConte or a closely allied species. W. J. Brown, of Ottawa, informs the writer that *confusus* LeConte is found in the woods and is the most common *Limonius* at Arnprior. Blatchley (1910, p. 758) reports that the adults of *confusus* are found beneath the bark of oak and other trees, but that the species is scarce in Indiana.

It is possible that there is some error in the reference by J. J. Davis (1911, p. 251) to *L. confusus* larvae damaging truck crops in Illinois. I have examined the larval exuvium of a specimen collected by Mr. Davis, the reared adult of which was identified by J. A. Hyslop as *Limonius confusus* LeConte. This larval skin bears structures of great similarity to those of the larva of *L. dubitans* LeConte, and on this basis Mr. Davis' species would be placed in the *canus* group, which includes *L. canus* and *L. dubitans* and their close allies. However, Mr. Brown, of Ottawa, informs me that, on the basis of adult characters, *confusus* and *dubitans* belong in distinct species groups. Blatchley (1910, p. 762) states that *L. dubitans* "resembles so closely *Limonius griscus* that it can with difficulty be separated." Both of these species occur commonly in Indiana and undoubtedly in Illinois. Davis' larva is more likely to be one of these soil-inhabiting species than the woodland *confusus*. It is unfortunate that the adults reared by Mr. Davis are either lost or misplaced and Mr. Hyslop's original identification cannot be checked.

The larva which is provisionally named *confusus* LeConte in the present study belongs to that group of *Limonius* that have very small outer urogomphal prongs. Its other chief characteristics are the presence of a mediodorsal groove on the ninth abdominal segment; prominent setae unpaired on abdominal mediotergites; eyes present; and paranasal lobes without a definite cluster of pores.

The largest larva examined measured 18 mm. in length. The ninth abdominal segment bears 2 very small (inconspicuous) setae anteriorly on dorsal plate; small, blunt "teeth" on lateral aspect of dorsum; and distance between caudal notch and pleural area approximates one-fifth total length of segment, exclusive of urogomphi. Nasale with tip

tridentate. Frontoclypeal area truncate posteriorly. Three lateroepicranial setae on each gena, arranged as a dorsal pair and 1 unpaired hair farther ventrad. Mandibles robust. Without setae on ventral surface of basal segment of labial palpus. With 1 to 4 setae (rarely spinelike) on each episternum of mesothorax and metathorax. Abdominal mediotergites with impressions not extending to middorsal suture; and bearing sparse, small punctures.

Specimens examined are deposited in the Canadian national collection.

LIMONIUS AEGER LeConte

FIGURES 11, *d*; 31, *d*

According to Van Dyke (1932, p. 339) this species occurs from Nova Scotia and the New England States west to British Columbia and south through the Rocky Mountains to New Mexico and from the Cascade Mountains to Mount Hood, Oreg. Larvae have been reared from Saskatoon, Saskatchewan.

Under Saskatchewan conditions this species is found in forest litter and in the superficial layers of soil under the litter. The larvae have been collected in greatest abundance under mixed shrubs and poplar along the banks of the Saskatchewan River. In the muck soils of southern Quebec and Ontario, larvae believed to be of this species are injurious to vegetables. Rearing records indicate that pupation normally occurs in soil or litter from late July to early August.

The larva of *aeger* belongs to that group of *Limonius* that have very small outer urogomphal prongs (*opr*, fig. 31, *d*). It shows superficial resemblance to the larva provisionally regarded as *confusus* LeConte, but differs as follows: Eyes absent; ninth abdominal segment without mediodorsal groove (sometimes with a shallow subcircular depression bearing short, paired paramedian grooves), and with a sinuate "impression" laterally near base of segment; prominent setae paired on mediotergites of abdominal segments; each paranasal lobe bearing a cluster of 12 or more "sensory" pores; and usually 4 to 7 spinelike setae on each episternum of mesothorax and metathorax.

The largest larvae attain 12 mm. in length. Ninth abdominal segment without setae on central dorsal area, small and much-rounded "teeth" on lateral aspect of dorsum, and distance between caudal notch and pleural area approximating one-fifth to one-fourth length of segment, exclusive of urogomphi. Nasale with tip tridentate. Subnasale of many fine teeth. Frontoclypeal area truncate posteriorly. Two prominent unpaired lateroepicranial setae on each gena. Abdominal

mediotergites with fine scattered punctures, and with transverse branches of impressions reaching about four-fifths of the distance from the longitudinal branches to the middorsal suture.

Material used in study.—Thirteen examples were examined, including the larval exuviae of three reared specimens. All material was from Saskatoon, Saskatchewan, and is now in the Canadian national collection. The reared adults were identified by W. J. Brown, of Ottawa. Notes follow on the reared material.

6; Saskatoon, Saskatchewan; July 13, 1935; 1 reared to adult July 30, 1935; R. Glen.

7; Saskatoon, Saskatchewan; July 21, 1937; 2 reared to adults Aug. 3, and Aug. 20; R. Glen and H. McDonald.

THE LIMONIUS CANUS GROUP

FIGURES 10, *e*; 11, *g*; 31, *b*, *c*, *f*; 32

PROVISIONAL KEY TO SPECIES [18]

1. From eastern North America, including the Great Lakes region....... 2
   From western North America, including the Great Plains region....... 3
2. Abdominal mediotergites (fig. 32, *c*) with impressions extending to or nearly to the middorsal suture on second to fifth segments; New York to Indiana..................................**dubitans** LeConte
   Abdominal mediotergites with shorter impressions; eastern Canada and northeastern United States.............{ **ectypus** (Say) (?) (= **agonus** Say) / **anceps** LeConte (?) }
3. Urogomphi with outer prongs hook-shaped (*opr*, fig. 31, *f*; eastern Washington, and Idaho to northern California..**subauratus** LeConte (?)
   Outer urogomphal prongs not hook-shaped (fig. 32, *e*, *f*).............. 4
4. Abdominal mediotergites with impressions (as in fig. 32, *c*) extending to or nearly to the middorsal suture on second to fifth segments...... 5
   Abdominal mediotergites with shorter impressions; British Columbia and the Pacific States....................................**canus** LeConte
5. From Manitoba, Saskatchewan, and Alberta...**Limonius** sp., near **ectypus** (Say)
   From the Pacific area......................{ **californicus** (Mannerheim) / **occidentalis** Candeze (?) }

The larvae of eight North American species have been included in this group. Of these, *L. canus* LeConte and *L. dubitans* LeConte

[18] Since this study was completed, H. P. Lanchester has published a paper containing a key to the larvae of six species of this group: "Larval Determination of Six Economic Species of Limonius," Ann. Ent. Soc. Amer., vol. 39, p. 619-626, 1946.

are believed to be reliably named. The larvae regarded as *L. ectypus* (Say) and *L. anceps* LeConte have been identified provisionally on the basis of geographic distribution and field association with adults of these species. Considerable uncertainty surrounds the identification of the larvae here designated as *subauratus* LeConte and *occidentalis* Candeze. The following changes might be in order: *L. subauratus* changed to *infuscatus* Motschulsky and *occidentalis* changed to *subauratus* LeConte. However, the names used in the present discussion are those that were found on the labels accompanying the specimens examined.

The *canus* group includes some of the most important pest species in America. All are soil inhabiting and all have been reported as injuring cultivated plants. With reference to the Pacific coast species. Lane (1935, p. 530) reports that the larvae inhabit moist soils, such as stream margins, low-lying lands, and irrigated fields, and thrive especially in alkaline areas. Similar habits have been observed for the larvae of "*Limonius* sp. near *ectypus* (Say)" occurring in the Prairie Provinces. The eastern species also are known to inhabit moist areas, but frequently are taken from sandy soils that are relatively well drained.

Very little has been published on the life history of these species, but it appears that pupation normally occurs in late July or early August, with the adults overwintering in their pupal chambers.

The morphology of the larva of *L. canus* LeConte has been studied in detail by Lanchester (1939).

Larvae of the *canus* group differ from other known *Limonius* larvae in that the prongs of the urogomphi are subequal in length. This group is further characterized as follows: Relatively large larvae, sometimes attaining 25 mm. in length when mature; each paranasal lobe with a cluster of 12 or more "sensory" pores (*pnlp*, fig. 32, *a*); eyes absent; with 1 small seta on ventral aspect of basal segment of labial palpus; maxillary palpus with second segment longest; 6 to 12 spinelike setae on each episternum of mesothorax and metathorax; abdominal mediotergites with prominent posterior setae arranged in pairs (fig. 32. *c*); dorsal plate of ninth abdominal segment (figs. 11, *g*; 32, *d, f*) with 2 or 4 unpaired setae, without mediodorsal groove (sometimes with shallow subcircular depression), and with well-rounded "teeth" (*to*) or tubercles on lateral margins; in ninth abdominal segment the distance between caudal notch and pleural area approximates one-sixth total length of segment, exclusive of urogomphi.

Material used in study of the group.—*L. anceps* LeConte: Examination was restricted to 10 larvae collected at Maxfield, Maine. These were provisionally identified by Dr. A. G. Böving, Washington, D. C., as *Limonius anceps* LeConte. (U.S.N.M.)

L. californicus (Mannerheim): Only four larvae were examined. These were reared from eggs secured from adults collected at Walla Walla, Wash., by M. C. Lane, and identified by him. (U.S.N.M.) These larvae were found to be identical to the larvae of *L. canus* LeConte, an error in labeling being the most plausible explanation. Consequently, the key characteristics of *L. californicus* larvae were taken from Lanchester (see footnote, p. 164).

L. canus LeConte: Examination was restricted to four larvae reared from eggs secured from adults collected at Walla Walla, Wash., by M. C. Lane and identified by him. (U.S.N.M.)

L. dubitans LeConte: Six larvae were studied. These were collected from Cornwells, Bucks County, Pa., by C. A. Thomas. Mr. Thomas has reared this larval type and he identified the larval material used as *L. agonus* Say. In a personal communication, Mr. Thomas informed the writer that the species previously identified as *L. agonus* Say is now regarded as being *L. dubitans* LeConte. (U.S.N.M.)

L. ectypus (Say) (?): Ten larvae collected at Chatham, Ontario, were examined. These specimens were taken from cultivated fields where adults of this species were very abundant, but identification was not confirmed by rearing. (C.N.C.)

Limonius sp., near *ectypus* (Say): Twelve examples, including the larval exuvium of one reared specimen, were studied. These specimens were collected from Souris, Manitoba (9), Taber, Alberta (2), and Radisson, Saskatchewan (1). W. J. Brown identified the reared adult. Material associated through rearing is listed below.

6; Souris, Manitoba; June 8, 1938; 1 reared to adult Aug. 16, 1938; H. W. Moore. (C.N.C.)

L. occidentalis Candeze (?): Three larvae were examined. These were in the same vial as five adults, all from Toppenish, Wash. As far as is known the identification was made on the basis of field association of larvae and adults. (U.S.N.M.)

L. subauratus LeConte: Four larvae from Spokane, Wash., were studied. These were taken from the Hagerstown, Md., collection and were labeled, "Web. No. 4675." Ledger records stated that two larvae bearing this number had been reared and their adults identified by J. A. Hyslop as *Pheletes subauratus* LeConte. However, neither the larval exuviae nor the reared adults could be found. (U.S.N.M.)

Genus ELATHOUS Reitter

ELATHOUS BICOLOR (LeConte)

FIGURES 11, *c*; 33, *a*, *b*

Elathous bicolor (LeConte) is the only species of this genus known in the larval stage. The larvae were collected from decaying wood at Baldwin Hill, Douglas County, Kans., on January 3. One specimen pupated on May 15 and the adult emerged June 4.

This species is undoubtedly closely related to *Athous* and *Lepturoides*, from which it differs by the combined characters of a small caudal notch and the outer urogomphal prongs being not longer than the inner prongs. It bears resemblance to the larva of *Ludius resplendens* (Eschscholtz), differing by having the outer urogomphal prongs sharp and inclining forward, and by the impressions on the abdominal mediotergites failing to reach the middorsal line. Distinction from *Limonius* larvae is obtained through the combination of prominent outer urogomphal prongs and the presence of a dorsal median groove on the ninth abdominal segment.

The principal characters of the larva of *E. bicolor* may be summarized as follows: Length 14 mm., not fully distended and probably not mature. Dorsum yellow brown. Caudal notch small. Urogomphi (*ur*, fig. 33, *b*; fig. 33, *a*) bifid; prongs subequal in length or outer prongs slightly shorter than inner prongs; outer prong (*opr*) corniform, projecting dorsad with sharp tip inclined forward. Ninth abdominal segment (fig. 33, *b*) with median dorsal groove (*mg*), without setae on central dorsal area, with 3 well-rounded "teeth" on each side of dorsum, and with distance between pleural area and caudal notch about one-fifth total length of segment, exclusive of urogomphi. Nasale with tridentate tip. Eyes present; surrounded by 3 or 4 unpaired setae. Two prominent lateroepicranial setae on each gena, the more dorsal seta paired with a very minute seta. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandible with well-developed retinaculum. Presternum of prothorax undivided. Mesothorax and metathorax with definite impressions on mediotergites and 3 or 4 spinelike setae on each episternum. Abdominal mediotergites with transverse branches of impressions reaching about three-fourths of distance from longitudinal branches to middorsal suture, and bearing small to moderate-sized shallow pits, but lacking transverse rugae.

Material used in study.—Two examples were examined, one being the exuvium of a reared specimen, the adult of which was identified

by W. J. Brown, of Ottawa. Both specimens were collected at the same time and in the same woods, but from separate decayed logs.

2: Baldwin Hill, Douglas County, Kans.; Jan. 3, 1933; 1 reared to an adult June 4, 1933; C. H. Hoffman. (C.N.C.)

Genus LEPTUROIDES Herbst

FIGURES 12, *b*; 33, *c-e*

In following Hyslop (1921), the generic name *Lepturoides* Herbst is used in preference to *Campylus* Fischer and *Denticollis* Piller and Mitterspacher, which are still commonly used by European workers.

Larvae of this genus are known for the European genotype, *Lepturoides linearis* (Linnaeus), and for the North American *denticornis* (Kirby), and a closely allied but unidentified larva from Alaska, which possibly is *fulvus* (Motschulsky). These larvae are very similar and further study and more material are required to secure reliable separating structural characters.

All known *Lepturoides* larvae inhabit the forest, usually occurring under the bark of decaying wood, especially in stumps and logs of deciduous trees. They are believed to be predaceous. Henriksen (1911, p. 269) states that *L. linearis* pupates in May and June, the newly formed adults emerging at once from their pupal chambers. In Pennsylvania, Knull (1934, p. 208) found a pupa of *Lepturoides productus* (Randall) on April 24, from which the adult emerged on May 4; and the author collected larvae of *L. denticornis* in Minnesota on April 8 from which two adults developed by May 4. From these observations, it would appear that in this genus hibernation is limited to the larval stage, that the overwintering larvae normally pupate with the first warm weather, and, in contrast to most Lepturoidini, the newly developed adults immediately leave their pupal cells for mating and egg laying.

On the basis of larval characters, *Lepturoides* is closely related to *Athous*. It is readily separated by the following combination of characters: Dorsum dark brown to black-brown; caudal notch small; outer urogomphal prongs (*opr*, fig. 33, *d, e*) very long, curving upward and forward: inner prongs (*ipr*) short and smooth, without posterior tubercles; abdominal mediotergites (fig. 33, *c*) punctulate, but without transverse rugae.

The larvae may exceed 20 mm. in length. Dorsum usually very dark, sometimes with a reddish undertone, darkest on prothorax and head; venter pale yellow or cream-colored. Ninth abdominal segment (fig. 33, *d*) with median dorsal groove (*mg*), without setae on cen-

tral area, with 3 or 4 prominent, sharp "teeth" (*to*) on each lateral margin, and with distance between pleural area and caudal notch about one-fifth total length of segment, exclusive of urogomphi. Nasale tridentate at tip. Subnasale with many fine teeth. Frontoclypeal area truncate posteriorly. Eyes large; bordered by 2 prominent unpaired setae. Two large unpaired lateroepicranial setae on each gena. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandible with prominent retinaculum, but without other teeth or toothlike expansions. Without setae ventrally on basal segment of labial palpus. Presternum of prothorax undivided. Mesothorax and metathorax with definite impressions on mediotergites, and up to 7 (usually 3 or 4) spinelike setae on each episternum. Abdominal mediotergites (fig. 33, *c*) with impressions reaching mediodorsal suture on all or most of segments, and with small fine punctures, but lacking transverse rugae.

Henriksen (1911, p. 269, fig. 62) depicts the larva of *L. linearis* with prominent rugae on the abdominal mediotergites. This condition was not found on any of the material examined.

PROVISIONAL KEY TO SPECIES OF LEPTUROIDES

1. From Europe .... **linearis** (Linnaeus)
   From North America 2
2. From eastern and central United States and Canada; impressions usually reaching middorsal suture on *all* abdominal mediotergites (fig. 33, *c*) .... **denticornis** (Kirby)
   From Alaska; impressions usually not reaching middorsal suture on first and eighth abdominal segments .... **fulvus** (Motschulsky) (?)

Material used in the study of the genus.—*L. linearis* (Linnaeus): Thirteen larvae were examined. These were from Denmark (7), Germany (1), Finland (1), and England (4). None of the specimens was known to be associated with reared material. Labeled larvae were received from the U. S. National Museum and from the British Museum of Natural History. These specimens undoubtedly were of the same species and definitely were congeneric with reared larvae of *Lepturoides denticornis* (Kirby). Therefore, it is believed that the material was properly identified.

L. denticornis (Kirby): Eight examples of this species were studied, including the exuviae of two reared specimens. All specimens were taken together from under the bark of an old fallen elm. W. J. Brown, of Ottawa, identified the reared adults.

8; Carter County, Minn.; Apr. 8, 1933; 2 reared to adults on May 4, 1933; R. Glen. (C.N.C.)

Lepturoides fulvus (Motschulsky) (?): Only one larva was examined. This specimen was from Alaska and the identification was made entirely on the basis of locality. (U.S.N.M.)

Genus ATHOUS Eschscholtz [14]

FIGURES 12, *a*, *c*; 34-36

Larvae of 14 species of *Athous* have been studied. These are primarily forest forms, living in the litter and decaying wood, and probably are chiefly predaceous. A few European species are found in woodland meadows and cause injury to plants when such areas are brought under cultivation. Larvae of this genus have not been recorded as crop pests in North America.

In America, *Athous* larvae collected in May and June frequently have pupated within a few days after being brought indoors. These findings suggest that some species of *Athous* normally transform to adults in June or early July. However, with species of the *vittatus* group, pupation is reported to occur in late July and August and the adults overwinter in their pupal chambers. Very little is known about the duration of larval life; for *A. haemorrhoidalis* (Fabricius), Roberts (1922, p. 316) suggests 3 or 4 years; for the common American species, there is evidence that indicates a shorter life cycle.

The undivided prosternum (*prst*, fig. 31, *c*), places *Athous* near *Hemicrepidius*, *Lepturoides*, *Elathous*, *Limonius*, and certain species of *Ludius*. Generic distinction is most readily obtained if the larvae of *Athous* are considered in two artificial groups as follows: *Group I*, caudal notch large (figs. 34, *h*; 35, *c*; 36, *a*); eyes present. *Group II*, caudal notch small (fig. 34, *c*, *d*); outer prongs of urogomphi much longer than inner prongs; dorsum yellow or yellowish brown. *Group I* resembles the larvae of *Hemicrepidius*, but is distinguished by the presence of eyes. *Group II* differs from *Lepturoides* larvae in color, and from the larvae of *Elathous*, *Limonius*, and allied *Ludius* by the long outer prongs. Larvae with large, deep pits or prominent transverse rugae on the abdominal mediotergites (figs. 34, *e*; 35, *e*; 36, *c*; 37, *b*) are either *Athous* or *Hemicrepidius*, depending upon the presence or absence of eyes. The Asiatic *Pleonomus* has been reported by Ghilarov (1937, p. 635) as inseparable in the larval stage from the European *Athous*, but specimens were not available for examination in the present study.

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[14] On the basis of larval characters the European *Athous niger* (Linnaeus) and a larva believed to be *Athous hirtus* (Herbst) are typical *Hemicrepidius* and are discussed under that genus.

Excluding *Athous niger* (Linnaeus) and its allies, all the *Athous* larvae examined had the following characters in common: Presternum of prothorax undivided. Urogomphi bifid, usually with prongs subequal or outer prongs longer than inner prongs. Dorsum of ninth abdominal segment with median sulcus, without setae on central area, and with prominent "teeth" (sometimes sharp) on lateral aspects. Nasale tridentate at tip, denticles subequal. Subnasale of many fine teeth. Eyes present. Two unpaired lateroepicranial setae on each gena. Gula of moderate length, but narrow. One "sensory" appendix on second segment of antenna. Mandible usually with well-developed retinaculum but lacking other teeth or toothlike expansions. Definite impressions on mediotergites of mesothorax and metathorax. Abdominal mediotergites with long impressions, reaching at least three-quarters of the distance to the mediodorsal suture; mediotergite sometimes with coarse deep pits or prominent transverse rugae.

KEY TO "SPECIES GROUPS" AND ISOLATED SPECIES OF ATHOUS

1. Caudal notch small (fig. 34, *c*, *d*) 2
   Caudal notch large (figs. 34, *h*; 35, *c*) or moderately large (fig. 36, *a*) .. 3
2. Abdominal mediotergites with numerous transverse rugae (fig. 34, *e*); North America .... the **rufifrons group** (p. 173)
   Abdominal mediotergites without transverse rugae; Europe .... the **vittatus group** (p. 171)
3. Urogomphi with outer prongs much longer than inner prongs (fig. 34, *h*); abdominal mediotergites without coarse punctures or prominent rugae; Europe .... **A. mutilatus** Rosenhauer (p. 174)
   Urogomphi with outer prongs not longer than inner prongs (figs. 35, *c*, *d*; 36, *a*); abdominal mediotergites with coarse, prominent sculpture (figs. 35, *e*; 36, *c*) 4
4. Caudal notch only slightly narrowed posteriorly (fig. 35, *c*, *f*); mandible (fig. 35, *a*) with medial expansion (*ex*) in region of penicillus; North America .... the **cucullatus group** (p. 175)
   Caudal notch considerably narrowed posteriorly (fig. 36, *a*, *d*); mandible without medial expansion at penicillus; Europe and North America.. .... the **undulatus group** (p. 177)

THE ATHOUS VITTATUS GROUP

FIGURE 34, *a-c*

PROVISIONAL KEY TO SPECIES

Inner prongs of urogomphi (fig. 34, *a*, *c*) with prominent posterior tubercle; outer prongs with small denticle on inner aspect (sometimes absent through erosion); fine sharp points on "teeth" (*to*) along lateral margins of dorsum of ninth abdominal segment........................ .... **A. haemorrhoidalis** (Fabricius)

Inner prongs (fig. 34, *b*) strongly convex posteriorly, but without tubercles as described above; without fine sharp points on "teeth" on ninth abdominal segment .... { **A. vittatus** (Fabricius) / **A. subfuscus** (Muller)

The species placed in this group are enumerated in the key and include *A. vittatus* (Fabricius), which is regarded by Mequignon (1930, p. 95) as the genotype of *Athous.*

Larvae of all species are reported to occur in decaying wood, but the typical larval habitat appears to be in the soil of grassy areas in and around forests. When such areas have been brought under cultivation, the larvae have been reported as damaging domestic plants. Pupation occurs in late July or during August, the adults hibernating in their pupal chambers.

This group may be identified by the following combination of characters: Dorsum bright yellow to yellow-brown; caudal notch small; urogomphi (fig. 34, *a-c*) with outer prongs much longer than inner prongs; abdominal mediotergites finely punctulate, but without prominent transverse rugae.

Larvae of *haemorrhoidalis* are reported by Henriksen (1911, p. 275) to attain a length of 24 mm.; the other species only 18 mm. All species have ninth abdominal segment with 4 prominent "teeth" on lateral margins of dorsum, and distance between caudal notch and pleural area approximating one-fifth of total length of segment, exclusive of urogomphi. Frontoclypeal area truncate posteriorly. Without small seta ventrally on basal segment of labial palpus. Up to 5 spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites with impressions reaching to or almost to middorsal suture on second to fifth segments, and with 5 to 8 setae (not definitely paired) in posterior transverse row.

Material used in the study of the group.—A. vittatus (Fabricius): Five larvae from Vemmetofte, Sealand (Denmark), were examined. These are not known to be associated with reared material, but were received fully labeled from Dr. Mathias Thomsen, Royal Veterinary and Agricultural College, Copenhagen. The identification is believed to be reliable. (C.N.C.)

A. haemorrhoidalis (Fabricius): Three larvae, from France, England, and Denmark, were studied. These were not identified through rearing, but the larva of this species is well known in Europe and the material used is believed to be reliably named. (B.M. and U.S.N.M.)

A. subfuscus (Müller): Five larvae were examined. These specimens were from Germany (2), Finland (1), and Denmark (2). As

far as is known this material was not associated with reared specimens, but the species has been reared in Europe and the material available was similar to that figured by Henriksen (1911, figs. 72-74) as *A. subfuscus*. (C.N.C. and U.S.N.M.)

THE ATHOUS RUFIFRONS GROUP

FIGURE 34, *d-f*

PROVISIONAL KEY TO SPECIES

1. Abdominal mediotergites (fig. 34, *e*) with coarse, conspicuous, transverse rugae; central and eastern United States and Canada.............. 2
   Abdominal mediotergites with shallow, less conspicuous rugae; along the coast and mountains from Alaska to California....................
   ....**A. pallidipennis** Mannerheim
2.[15] Urogomphi (fig. 34, *d*) with inner prongs (*ipr*) somewhat ensiform; usually in decaying wood, rarely in leaf litter..**A. rufifrons** (Randall)
   Urogomphi (fig. 34, *f*) with inner prongs (*ipr*) more subquadrate; known only from damp decaying forest litter....**A. brightwelli** (Kirby)

This group is described from the larvae of three North American species. Larvae of *A. rufifrons* have been collected in New Brunswick, Canada, and in Minnesota, Maryland, and Delaware, but larvae of *A. brightwelli* have been taken only in Pennsylvania although the adults are known as far west as Indiana (Blatchley, 1910, p. 759). Larvae of the western *A. pallidipennis* are known only from Walla Walla, Wash.

These are all forest species and probably are chiefly predaceous. Rearing notes for *rufifrons* show that larvae collected in April have matured to adults in May, suggesting that the normal time of pupation is early summer.

Larvae of this group are characterized by the yellow-brown color, the small caudal notch, urogomphi (fig. 34, *d, f*) with outer prongs much longer than inner prongs, and abdominal mediotergites (fig. 34 *e*) with an abundance of transverse rugae.

Mature larvae may exceed 20 mm. in length. Ninth abdominal segment with 4 "teeth" (the most posterior "tooth" usually large and sharp) on each side of dorsum, and distance between caudal notch and pleural area about one-fifth to one-fourth total length of segment,

[15] The characters used for separating *rufifrons* and *brightwelli* are entirely provisional. Only larval exuviae of *brightwelli* were available for examination and further study of whole larvae is necessary before better key characters can be given. The data on habitats probably are insufficient to serve as a basis of separation.

exclusive of urogomphi. Frontoclypeal area truncate posteriorly. Without seta on basal segment of labial palpus. Up to 6 (usually 3 or 4) spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites with impressions usually reaching to middorsal line on second to sixth segments, and with 5 to 10 unpaired setae in an irregular posterior transverse row.

Material used in the study of the group.—Reared material was available for *rufifrons* and *brightwelli.* W. J. Brown, of Ottawa, identified the reared adults.

A. rufifrons (Randall): Ten examples were examined, including the exuviae of three reared specimens. Eight of the total were from Minnesota, one from Delaware, and one from Maryland. Material associated with available reared adults is listed below.

8; Carter County, Minn.; Apr. 8, 1933; 2 adults emerged May 3, and May 4, 1933, respectively; R. Glen. (C.N.C.)

1; Centerville, Del.; Apr. 12, 1930; adult emerged May 17, 1930; C. A. Thomas. (Pa.C.)

A. brightwelli (Kirby): Only the larval exuviae of two reared specimens were available for study.

2; Cornwells, Pa.; April 1927; C. A. Thomas. (Pa.C. and C.N.C.)

A. pallidipennis Mannerheim: Eight larvae from Walla Walla, Wash., were examined. These were collected and identified by M. C. Lane. (U.S.N.M.)

ATHOUS MUTILATUS Rosenhauer

FIGURES 12, *c*; 34, *g, h*

This European species was studied from larvae collected in Germany and Denmark. Specimens collected from decaying elms were reported reared to maturity.

Larva of *A. mutilatus* are not closely allied to other known *Athous* larvae and may be distinguished by the following characters: Caudal notch large, only slightly narrowed posteriorly; urogomphi (fig. 34, *g, h*) with outer prongs much longer than inner prongs; outer prongs corniform, tips sharp; and abdominal mediotergites punctulate, but lacking transverse rugae and coarse pits.

The larvae examined measured up to 13 mm. in length. Dorsum pale yellow to yellowish brown with head and thorax distinctly darker. Ninth abdominal segment with 3 rounded "teeth" on each lateral margin of dorsum, and distance between caudal notch and pleural

area approximating one-sixth of total length of segment, exclusive of urogomphi. Frontoclypeal area bluntly rounded posteriorly. Without setae ventrally on basal segment of labial palpus. Third segment of antenna as long as second segment. With 3 or 4 spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites with impressions extending to the middorsal suture on second to eighth segments, inclusive, and with 5 to 7 prominent setae in posterior transverse row, none definitely paired.

Material used in study.—Four larvae were examined, one from Dyrehaven, Denmark, and three from Lossnig (near Leipzig), Germany. The German specimens were labeled "reared," but adults and larval exuviae of reared specimens were not available to the writer. (Canadian national, U. S. National Museum, and van Emden collections.)

THE ATHOUS CUCULLATUS GROUP

FIGURES 12, *a*; 35

KEY TO SPECIES

1. Ninth abdominal segment (fig. 35, *c*) with large deep pits on dorsum; larva usually dark brown; urogomphi with outer prongs slightly shorter than inner prongs (fig. 35, *c, d*); Manitoba and Minnesota to Atlantic coast.................................. **cucullatus** (Say)
   Ninth abdominal segment (fig. 35, *f*) with small, sparse punctures on dorsum; larva yellowish brown; urogomphi with prongs subequal in length 2
2. Abdominal mediotergites with the 2 most medial setae occurring close together in a definite "paired" arrangement (fig. 35, *e*); known from Illinois and Tennessee to Atlantic coast.............. **scapularis** (Say)
   Abdominal mediotergites with the 2 most medial setae well separated, not more than "semipaired"; British Columbia and Alberta to California and Arizona........................... **nigropilis** Motschulsky

On the basis of larval characters, the three North American species listed above have been placed in the same group, but *scapularis* and *nigropilis* are most closely allied. The larvae of all species have been identified through rearing.

These are all forest forms, the larvae occurring chiefly in decaying wood. Rearing records and adult captures indicate that pupation normally occurs in early summer, the adults being most numerous in July.

Larvae of the *cucullatus* group differ from all other known elaterid larvae in the mandible (fig. 35, *a*), which bears a prominent medial expansion in the region of the penicillus. However, the larvae may be more easily recognized by the following combination of characters: Caudal notch large (*cn*, fig. 35, *c, f*), only slightly narrowed pos-

teriorly; urogomphal prongs subequal, or inner prongs (*ipr*) longer than outer prongs, outer prongs (*opr*) with bluntly rounded tips; prominent transverse rugae on abdominal mediotergites (fig. 35, *e*), especially on third, fourth, and fifth segments.

Mature larvae usually measure 16 to 19 mm. in length. Dorsum dark brown (*cucullatus*) or yellowish brown. Ninth abdominal segment (fig. 35, *c, f*) with (*cucullatus*) or without conspicuous, large pits on dorsum, with 3 prominent "teeth" (usually blunt) on each lateral margin of dorsum, and with distance between caudal notch and pleural area approximating one-ninth to one-sixth total length of segment, exclusive of urogomphi. Frontoclypeal area truncate posteriorly. Without setae on ventral aspect of basal segment of labial palpus. Up to 9 (usually 6 or 7) spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites (fig. 35, *e*) with impressions reaching to middorsal suture on some segments; transverse rugae on anterior segments give place to circular pits on posterior segments; and usually 5 or 6 prominent setae in posterior transverse row.

Material used in the study of the group.—As stated above, reared material was available for all three species. All the reared adults were identified by W. J. Brown, Ottawa.

A. cucullatus (Say): The 12 specimens examined were collected in Minnesota (1), Illinois (6), Mississippi (1), and Pennsylvania (4). In four instances larval skins were preserved with reared adults, but only one of the available whole larvae was directly associated with a reared specimen, through being collected at the same time and place. Material for which the reared adults are available is detailed below:

1; St. Paul, Minn.; adult emerged June 4, 1933; R. Glen. (C.N.C.)
1; Hummelstown, Pa.; (no date); J. N. Knull. (U.S.N.M.)
2; Cornwells, Pa.; April 1927; 1 reared; C. A. Thomas. (Pa.C.)
1; Crowell Woods, Pa.; adult emerged June 25, 1930; C. A. Thomas. (Pa.C.)

A. scapularis (Say): Nine specimens were examined. These were from Illinois (3), Tennessee (1), Maryland (1), Pennsylvania (2), and Delaware (2). The larval skins of 3 reared specimens were studied, but none of the available whole larvae were directly associated with the reared material, being from different localities. Material for which the reared adults are known to be available is listed below:

1; Reelfoot, Tenn.; adult emerged May 21, 1936; A. P. Arnason. (C.N.C.)
2; Centerville, Del.; Apr. 12, 1930; 1 adult emerged June 21, 1930, other specimen pupated June 10, 1930; C. A. Thomas. (Pa.C.)

A. nigropilis Motschulsky: Eight specimens were examined, including the exuviae of three larvae reared to adults. All were collected from the same cottonwood stump.

8: Lethbridge, Alberta; June 5, 1935; 3 reared adults emerged June 23, July 12, and July 12, respectively; R. Glen. (C.N.C.)

THE ATHOUS UNDULATUS GROUP

FIGURE 36

KEY TO SPECIES

Urogomphi (fig. 36, *a*) with outer prongs slightly shorter than inner prongs; dorsum of ninth abdominal segment with conspicuous pits anteriorly; mesothorax and metathorax with well-developed impressions on mediotergites..**A. undulatus** (DeGeer)

Urogomphi (fig. 36, *d*) with prongs subequal; dorsum of ninth abdominal segment with conspicuous pits both posteriorly and anteriorly; mesothorax and metathorax with very short impressions on mediotergites... ....**A. villosus** (Geoffroy)

The larvae of *Athous* (*Harminius*) *undulatus* (DeGeer) and *Athous villosus* (Geoffroy) (=*A. rhombeus* Olivier) are sufficiently closely allied to be placed in the same group until the larvae of other related species are available for examination. Both species occur in Europe and *undulatus* is reported by Van Dyke (1932, p. 368) also to inhabit the Hudson Bay and Lake Superior regions of North America. The larvae are found in decaying wood and are believed to be predaceous.

Larvae of this group superficially resemble those of *Athous cucullatus* (Say), but differ in characters of the mandible, sculpture of abdominal mediotergites (fig. 36, *c*), and shape of the caudal notch (fig. 36, *a, d*).

Mature larvae usually exceed 20 mm. in length. Dorsum is dark brown to brownish black, with large, deep pits, sometimes confluent in second to sixth segments. Venter pale yellow. Caudal notch at least moderately large, subcircular, much narrowed posteriorly. Urogomphi (fig. 36, *a, b, d, e*) with subequal prongs, or with inner prongs longer than outer prongs; outer prongs (*opr*) with bluntly rounded tips. Ninth abdominal segment with large, deep pits on dorsum; sometimes (*villosus*) with 2 fine setae anteriorly on dorsal plate; with 3 prominent blunt teeth on each lateral margin of dorsum; and distance between caudal notch and pleural area approximating one-eighth of total length of segment, exclusive of urogomphi. Frontoclypeal area truncate (*villosus*) or broadly rounded (*undulatus*) posteriorly. Man-

dible without medial expansion in region of penicillus (thus differing from *A. cucullatus* group, fig. 35, *a*). Without setae on ventral surface of basal segment of labial palpus. Up to 5 spinelike setae on each episternum of mesothorax and metathorax. Abdominal mediotergites (fig. 36, *c*) with impressions of variable length, sometimes appearing to extend to middorsal suture on second to fifth segments, but usually difficult to distinguish impressions from confluent adjoining pits; from 6 to 10 setae in posterior transverse row, usually some arranged in pairs.

Material used in the study of the group.—*A. undulatus* (DeGeer): Four larvae from Finland were examined. The larva of this species has been known in Europe for many years and the writer believes that this material is reliably identified although probably not directly associated with reared specimens. (C.N.C. and U.S.N.M.)

A. villosus (Geoffroy): Four specimens from Denmark were examined, including the exuvium of one specimen said to have been reared. The adult of this specimen was not available to the writer, but the label stated "adult det. by August West." It is also known that August West (1937, p. 484) has reared the larva of *Athous villosus* from Dyrehaven, Denmark.

1; Bognaes, Denmark; (no date); reared; J. P. Kryger (U.S.N.M.; adult probably in A. West's collection, Denmark).

Other specimens examined are deposited in the Canadian national and the U. S. National Museum collections.

Genus HEMICREPIDIUS Germar

FIGURES 12, *d, f;* 37, *a-c*

Species of *Hemicrepidius* are commonly recorded in the older North American literature under the generic name *Asaphes* Kirby.

Characters of this genus have been based upon the larvae of *H. memnonius* (Herbst), *H. hemipodus* (Say) (= *decoloratus* Say), *H. bilobatus* (Say), *H. carbonatus* (LeConte), and a larva, the reared adult of which was identified as "*Hemicrepidius* sp. near *carbonatus* (LeConte)." Larvae of the European *Athous niger* (Linnaeus) and a larva which might be *Athous hirtus* (Herbst) have been included with *Hemicrepidius* in the present discussion since these possess typical *Hemicrepidius* characters.

H. hemipodus and *H. carbonatus* are the only American species that have been collected in numbers suitable for adequate characterization of their larvae. Other species seem to be rare, with the re-

sult that single specimens are taken and reared to adults leaving only the larval exuviae for examination. Additional material and further study are required for sound selection of key characters and for the definition of "species groups" within the genus.

A single larva of *Hemicrepidius* sp. was collected from a decaying cottonwood stump on the banks of the Old Man River at Lethbridge, Alberta. Decaying wood may be the typical habitat of this species, but the larvae of the other species are known to be primarily soil inhabiting, preferring moist soils such as woodland meadows and only rarely occurring in forest litter or in decaying wood.

H. memnonius (Herbst) has been reared from a New Brunswick garden, and from leaf litter in Pennsylvania. However, the species is recorded as far west as Alberta. *H. bilobatus* (Say) and *H. hemipodus* (Say) appear to be more truly eastern, not being recorded from west of the Great Lakes.

H. hemipodus is the only species commonly encountered in the larval stage. It has been taken from cornfields and other cultivated or pasture land from Maine to Illinois, but apparently it does not cause very severe crop injury. Forbes (1892, p. 39) suggests that this may be due in part to the early date at which larval activity ceases, pupation occurring normally in May or June. The newly formed adults appear to leave their pupal cells immediately. Similar habits of pupation and adult emergence are reported (Henriksen, 1911, p. 274) for *Athous niger,* and rearing records of other *Hemicrepidius* larvae indicate that pupation normally occurs relatively early in the summer. This biological character is common to *Hemicrepidius, Lepturoides,* several American species of *Athous,* and possibly *Elathous.* However, Blatchley (1910, p. 770) reports finding adults of *H. memnonius* in Indiana from June 8 to December 27, hibernation occurring beneath the bark of red oak logs.

On the basis of larval structure, *Hemicrepidius* is very closely related to *Athous.* Distinction is most readily obtained through the absence of eyes in *Hemicrepidius.* Other important characters are: Dorsum yellowish brown, never dark brown: large caudal notch; urogomphal prongs (fig. 37, *c*) subequal, or outer prongs slightly longer; abdominal mediotergites (fig. 37, *b*) with conspicuous transverse rugae, and with impressions reaching to middorsal suture in some segments. The urogomphal prongs show considerable individual variation; in typical specimens each prong has a short, sharp tip, but this is frequently worn away, especially on the outer prongs, giving them the smooth, rounded appearance found in *Athous cucullatus* (Say) and its allies.

Only large and moderate-sized species are known, the mature larvae usually exceeding 20 mm. in length. Dorsum of ninth abdominal segment (fig. 37, *c*) with median dorsal groove (*mg*), without setae on the central area, frequently with noticeable pits, and with 3 or 4 prominent "teeth" (*to*) on each lateral margin. Nasale tridentate at tip. Subnasale of many fine teeth. Two unpaired lateroepicranial setae on each gena. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandible (fig. 37, *a*) usually with relatively short retinaculum (*ret*). Presternum of prothorax undivided. Mesothorax and metathorax with distinct impressions on mediotergites, and up to 8 spinelike setae on each episternum. Each abdominal mediotergite with 5 or more prominent, unpaired setae in posterior row.

PROVISIONAL KEY TO SPECIES OF HEMICREPIDIUS

1. From Europe 2
   From North America.... 3
2. Distance between caudal notch and pleural area of ninth abdominal segment about one-seventh total length of segment, exclusive of urogomphi; frontoclypeal area almost pointed posteriorly.... **Athous hirtus** (Herbst) (?)
   Distance between caudal notch and pleural area about one-fifth length of segment; frontoclypeal area truncate posteriorly.... **Athous niger** (Linnaeus)
3. Inhabiting rotten wood; collected at Lethbridge, Alberta.... **Hemicrepidius** sp., near **carbonatus** (LeConte)
   Inhabiting soil, rarely in forest litter.... 4
4. Basal segment of labial palpus with small seta ventrally; western North America (larvae from Walla Walla, Wash.).... **H. carbonatus** (LeConte)
   Basal segment of labial palpus without seta; east of Rocky Mountains.... **H. memnonius** (Herbst) / **H. hemipodus** (Say) / **H. bilobatus** (Say)

Material used in study of the genus.—Reared adults of the following species of *Hemicrepidius* have been identified by W. J. Brown, of Ottawa: *memnonius* (Herbst), *hemipodus* (Say), *bilobatus* (Say), and "*Hemicrepidius* sp., near *carbonatus* (LeConte)." Reared material was also available of *Athous niger* (Linnaeus).

H. memnonius (Herbst): The larval exuviae of 3 reared specimens were examined, but no reliably named whole larvae were available.

2; Fredericton, New Brunswick; (no date); both reared; R. P. Gorham. (C.N.C.)
1; Cornwallis, Pa.; April 1927; reared; C. A. Thomas. (Pa.C.)

H. hemipodus (Say): Eight examples were studied, including the exuviae of four reared specimens. Unfortunately, the reared specimens were not collected at the same time and place as the whole larvae that were available.

1; Orono, Maine; Aug 1, 1929; reared; J. H. Hawkins. (U.S.N.M.)
3; Downingtown, Pa., Apr 10, 1930; adults emerged May 13, June 2, June 12, 1930; C. A. Thomas. (Pa.C.)

H. bilobatus (Say): Only the exuvium of 1 reared specimen was studied.

1; Hulmeville, Pa.; Apr. 13, 1927; reared; C. A. Thomas. (Pa.C.)

H. carbonatus (LeConte): Eight larvae were examined. These were collected at Walla Walla, Wash., by M. C. Lane and identified by him. (U.S.N.M.)

Hemicrepidius sp., near *carbonatus* (LeConte): Only the exuvium of one reared specimen was available.

1; Lethbridge, Alberta; June 5, 1935; adult emerged July 12, 1935; R. Glen. (C.N.C.)

Athous niger (Linnaeus): Seven specimens were studied, including the exuviae of two that were reared. None of the whole larvae was from the same collection as the reared material, but specimens were examined that were used by K. L. Henriksen (1911) in his description of this species. The material was from Denmark (5), Holland (1), and Germany (1). (U.S.N.M.)

2; Denmark; 1895; both reared; A. Ditlevsen. (R.V.A.C.)

Athous hirtus (Herbst) (?): Examination of this species was limited to a single specimen from France labeled as "*Athous hirtus* Hbst. or *niger* L.?" This larva differed slightly from available specimens of *A. niger*. (van Emden.)

Genus CREPIDOMENUS Erichson

CREPIDOMENUS QUEENSLANDICUS Blair

FIGURES 10, *f*; 37, *d-f*

This Australian species is the only *Crepidomenus* known in the larval stage. Specimens were received for study through the courtesy of W. A. McDougall, Assistant Entomologist, Central Sugar Experi-

ment Station, Mackay, Queensland, and from the British Museum of Natural History, London.

According to McDougall (1934, pp. 60, 65, 67; "*B sp.*") the larvae inhabit the soil of cultivated fields and grasslands; feeding normally occurs only during short periods immediately after each ecdysis; the complete larval life is probably less than 1 calendar year; and pupation occurs in September or early October, the adults being found in greatest numbers as early as the middle of October.

In structure, the larva of *C. queenslandicus* resembles the larvae of the genus *Cryptohypnus,* particularly in possessing dorsal postero-epicranial setae (as in fig. 10, *g, ped*), and medial anterotergal setae (*atm,* figs. 10, *g;* 37, *d*) in thorax and abdomen. It is distinguished by the following characters: Dorsum of ninth abdominal segment (fig. 37, *e, f*) with sharp "teeth" (*to*) on the lateral margins, and only 2 setae on the central area; abdominal mediotergites (fig. 37, *d*) with long impressions and lacking seta number 7 as numbered in *Cryptohypnus* (fig. 38, *f*).

Larvae examined measured up to 19 mm. in length; dorsum yellowish brown to pale chestnut brown; rather densely set with small punctures. Caudal notch large, not narrowed posteriorly. Urogomphi (*ur,* fig. 37, *e, f*) usually with prongs subequal in length, inner prongs (*ipr*) sometimes longer and always slightly more robust than outer prongs (*opr*). Ninth abdominal segment (fig. 37, *e, f*) without median dorsal groove, and distance between pleural area and caudal notch approximating one-fifth to one-fourth length of segment, exclusive of urogomphi. Nasale with tridentate tip, lateral denticles only slightly smaller than median denticle. Frontoclypeal area rounded posteriorly. Eyes present; surrounded by 4 setae. Three unpaired lateroepicranial setae on each gena. Gula moderately long, but very narrow. One "sensory" appendix on second segment of antenna. Mandible with prominent retinaculum. Presternum of prothorax divided, the median posterior piece being small. Mesothorax and metathorax with distinct impressions on mediotergites, and without spine-like setae on episterna. Abdominal mediotergites (fig. 37, *d*) with transverse branches of impressions reaching four-fifths to five-sixths of distance from longitudinal branches to middorsal suture. Abdominal pleurites large, subequal from first to eighth segments.

Material used in study.—Thirty larvae were examined. All were collected at Mackay, Queensland, by W. A. McDougall, who succeeded in rearing this species. (C.N.C. and B.M.)

Genus CRYPTOHYPNUS Eschscholtz

FIGURES 10, *g*; 38

The name *Cryptohypnus* has been used in the present study for species which, on the basis of larval characters, obviously are allied to *Cryptohypnus riparius* (Fabricius) (=*Hypnoidus riparius*), and for which American authors recently have shown a preference for the generic name *Hypolithus* Eschscholtz. The name *Hypnoidus* Stephens is restricted to species whose larval characters stamp them as being congeneric with *H. dubius* (Horn) and generically distinct from *riparius* and its close allies.

Characters given for this genus are based upon a study of the larvae of the five species listed in the key. All are believed to be soil inhabiting, and some are important crop pests.

These larvae superficially resemble *Melanactes densus* and the *Ludius nitidulus* group but are much more closely allied to the genus *Crepidomenus*. *Cryptohypnus* larvae are distinguished by a combination of characters involving setal arrangement, sculpture, and features of the ninth abdominal segment, the following being of primary significance: Head bearing dorsal posteroepicranial setae (*ped*, figs. 10, *g*; 38, *a*); each thoracic segment and first 8 abdominal segments bearing medial anterotergal setae (*atm*, figs. 10, *g*; 38, *f*); abdominal mediotergites with impressions and setal pattern as in figure 38, *f*, setae numbered 1 to 9 being present in all species; dorsum of ninth abdominal segment (fig. 38, *i*) bearing 4 setae on central plate and blunt "teeth" (*to*) on the margins.

The species studied rarely exceed 16 mm. in length. Dorsum yellow to yellowish brown; finely punctulate. Caudal notch (*cn*) large. Urogomphi bifid, prongs subequal in length (fig. 38, *e*, *g*) or inner prongs longer (fig. 38, *h*, *i*). Ninth abdominal segment without median dorsal groove, and distance between pleural area and caudal notch varies from one-sixth to one-fourth length of segment, exclusive of urogomphi. Nasale (*n*, fig. 38, *b-d*) typically tridentate; lateral denticles may be serrate (fig. 38, *d*) or absent through erosion. Eyes present. Gula moderately narrow. One "sensory" appendix on second segment of antenna. Mandibles of same type as in *Ludius aeripennis*. Presternum of prothorax of more than 1 piece, the median posterior sclerite being very narrow and often indistinct. Mesothorax and metathorax with distinct impressions on mediotergites; and with 1 to 3 setae on each episternum, setae usually fine or with only 1 being spinelike. Abdominal pleurites well developed, decreasing in size from first to eighth segments.

KEY TO SPECIES OF CRYPTOHYPNUS

1. Urogomphal prongs subequal (fig. 38, *e*, *g*); eastern North America.... ....**abbreviatus** (Say) (p. 185)
   Inner prongs of urogomphi longer than outer prongs (fig. 38, *h*, *i*).... 2
2. Nasale (*n*, fig. 38, *d*) with several small denticles on each side of base of median tooth, western North America .. **funebris** Candeze (p. 185)
   Nasale (*n*, fig. 38, *b*) tridentate, lateral denticles sometimes absent through erosion.. ....(the **riparius** group, p. 184) 3
3. From Europe.......................... ....**riparius** (Fabricius)
   From North America.. 4
4. Basal segment of labial palpus with 1 seta ventrally.........**sanborni** Horn
   Basal segment of labial palpus without setae......**nocturnus** (Eschscholtz)

THE CRYPTOHYPNUS RIPARIUS GROUP

FIGURES 10, *g*; 38, *b*, *h*, *i*

Included in this group are *riparius* (Fabricius), *nocturnus* (Eschscholtz), and *sanborni* Horn. All live in the soil. *C. nocturnus* is reported by King (1928, pp. 703-704) as an important pest of grain crops in Saskatchewan, and Evans (1921) suggests that *riparius* might injure field crops in Scotland.

This is a very homogeneous group, well characterized by the urogomphi and caudal notch (fig. 38, *h*, *i*) and by the nasale and subnasale (fig. 38, *b*).

These larvae seldom exceed 13 mm. in length. The inner prongs of the urogomphi are about twice as long as the outer prongs; the tips of the outer prongs turn slightly inward. The large, U-shaped caudal notch is not narrowed posteriorly except in a few atypical specimens. In the tridentate nasale, the lateral denticles are often weakly developed and sometimes are eroded away, giving a unidentate appearance. The frontoclypeal area is broadly rounded posteriorly.

Material used in the study of the group.—*C. riparius* (Fabricius): Eight larvae were examined. These were from Denmark (5), Finland (1), Russia (1), and Ireland (1). The specimens studied are believed to be reliably named, because the larva of this species is well known in Europe and some of the available material was used by K. L. Henriksen (1911) in his description of this species. (B.M. and U.S.N.M.)

C. nocturnus (Eschscholtz): Thirteen examples were studied, including the exuviae of four reared specimens. The reared adults were identified by W. J. Brown, of Ottawa.

10; Barnwell, Alberta; June 6, 1935; 2 adults emerged Aug. 8 and Aug. 9, 1935; R. Glen. (C.N.C.)

1; Taber, Alberta; June 6, 1935; adult emerged Jan. 31, 1936; R. Glen and G. F. Manson. (C.N.C.)
2; Turtleford, Saskatchewan; June 10, 1937; 1 adult emerged Aug. 3, 1937; J. V. Brooks. (C.N.C.)

C. sanborni Horn: Twenty specimens were studied, all from Churchill, Manitoba. A reared adult was identified by W. J. Brown, of Ottawa.

20; Churchill, Manitoba; June and July 1937; 1 adult emerged in July 1937; W. J. Brown. (C.N.C.)

CRYPTOHYPNUS FUNEBRIS Candeze

FIGURE 38, *d, f*

This western species is distinguished by the numerous denticles on nasale and subnasale (fig. 38, *d*), and by the frontoclypeal area, which is bluntly pointed posteriorly. The caudal notch is U-shaped and is not narrowed posteriorly. The urogomphi have the inner prongs longer than the outer prongs but less than twice as long. The setal pattern on abdominal mediotergites is given in figure 38, *f*. Larvae of this species are larger than other known *Cryptohypnus*, those at hand measuring about 16 mm. in length.

Material used in study.—Only 2 larvae were available for examination. These were collected, along with adults of this species, at Walla Walla, Wash., by M. C. Lane, and identified by him. It is not known that larvae of this type have actually been reared to adults, but Mr. Lane has expressed his confidence in the identification made. (U.S.N.M.)

CRYPTOHYPNUS ABBREVIATUS (Say)

FIGURE 38, *a, c, e, g*

This species is widely distributed in the eastern United States and from Newfoundland as far west as Saskatchewan. It is an important pest in fields and gardens. The larva differs from other known *Cryptohypnus* in having the urogomphal prongs (fig. 38, *e, g*) subequal; the caudal notch subcircular, or transversely subovate, and considerably narrowed posteriorly; the subnasale (fig. 38, *c*) with about 7 or 8 denticles; and the frontoclypeal area (fig. 38, *a*) rounded posteriorly. The lateral denticles of nasale are sometimes eroded, giving the appearance of a unidentate structure. Fully distended mature larvae measure up to 12 mm. in length.

Material used in study.—Examination was made of 12 examples, including the exuviae of 4 reared specimens. The reared adults were identified by W. J. Brown, of Ottawa.

3; Rhein, Saskatchewan; June 11, 1930; 2 adults emerged July 21 and Aug. 6, 1930; E. Mengering. (C.N.C.)

9; Spencerville, Grenville County, Ontario; June 23, 1938; 2 adults emerged Aug. 26 and Sept. 2, 1938; G. H. Hammond. (C.N.C.)

Genus HYPNOIDUS Stephens

FIGURES 9, *f*; 10, *b*; 39

The name *Hypnoidus* is used here in the restricted sense and does not include the species which are commonly referred to the genus *Cryptohypnus*.

Knowledge of this genus is based upon an examination of larvae of *dubius* (Horn), *musculus* (Eschscholtz), and the European *maritimus* Curtis. These species are very similar and it might be that they represent only one group within the genus. All are believed to be soil inhabiting and *dubius* is recorded by King (1928, p. 705) as being of economic importance in Saskatchewan. Kincaid (1900, pp. 374-375) described the larva of *musculus* from Alaska.

The known *Hypnoidus* larvae rarely exceed 11 mm. in length, are very pale yellow in color and are readily identified by the absence of spinelike setae on the coxae (fig. 39, *e*), by the mandibles (fig. 39, *c*, *g*) and by the pointed, undivided urogomphi (fig. 39, *f*, *h*, *i*). Sometimes, especially in *musculus*, a slight tubercle is present on the lateroposterior aspect of each urogomphus, which might be interpreted as an extremely small outer prong.

The caudal notch (*cn*) is large, usually transversely ovate and more or less narrowed posteriorly. The ninth abdominal segment lacks the transverse impression, the median sulcus, and the "teeth" on lateral margins, but bears 4 setae on central dorsal area. Nasale (*n*, fig. 39, *a*) consists of 3 short, subequal teeth, lateral denticles somewhat serrate in *maritimus*. Frontoclypeal area pointed posteriorly. Eyes lacking. Gula (fig. 39, *b*) very long and narrow. One "sensory" appendix on second segment of antenna. Galea reduced to a single segment. Mandible (fig. 39, *c*, *g*) with small retinaculum (*ret*), and finely serrate posterior to base of retinaculum. No distinct impressions on mediotergites of mesothorax and metathorax. Without spinelike setae on thoracic episterna. Abdominal mediotergites slightly rugose,

not punctured, impressions indistinct, and prominent setae unpaired. Abdominal pleurites (*pl*, fig. 39, *d*) large, sterna (*st*) undivided.

PROVISIONAL KEY TO SPECIES OF HYPNOIDUS

1. From North America 2
   From Europe .... **maritimus** Curtis
2. Mandible (fig. 39, *g*) usually with about 5 or 6 fine denticles at base of retinaculum .... **musculus** (Eschscholtz)
   Mandible (fig. 39, *c*) usually with about 2 fine denticles at base of retinaculum .... **dubius** (Horn)

Material used in study of the genus.—Reared adults of *H. dubius* (Horn) and *H. musculus* (Eschscholtz) were identified by W. J. Brown, of Ottawa.

H. dubius (Horn): Six specimens from Saskatoon, Saskatchewan, were examined, including the exuvium of one reared specimen. (C.N.C).

1: Saskatoon, Saskatchewan; May 27, 1924; adult emerged June 25, 1924. K. M. King.

H. musculus (Eschscholtz): Four larvae were studied. These were collected by T. Kincaid from Popoff Island, Alaska, and were the specimens upon which he based his description. An adult which was reared from a larva apparently collected at the same time and place is in the U.S. National Museum, but the associated larval skin could not be found.

H. maritimus Curtis: Six larvae from Austria were examined. These were identified through field association with adults of this species. However, the larvae show typical *Hypnoidus* characters and there is good reason to believe that the identification probably is correct. (Canadian national and British Museum collections.)

Genus EANUS LeConte

FIGURE 40, *a-e*

Species of *Eanus* are commonly recorded in the European literature under the generic name *Paranomus* Kiesenwetter.

Larvae of this group inhabit the litter of the northern and alpine forests and are probably chiefly predaceous. *E. decoratus* has been reared from Quebec and larvae have been collected as far west as Saskatchewan. According to Brown (1930, p. 163) adults of this species are known from the Gulf of St. Lawrence to Alaska. A larva

believed to be *E. costalis* was described from Finland by Prof. U. Saalas (1937, pp. 68-72, "Probably *Orithales serraticornis* Payk."; 1938, pp. 53-55), who kindly loaned the writer material for examination.

These two species are very similar in structure and are most readily separated on the basis of geographic distribution. However, Brown (1930, p. 162) has indicated that they represent only one of the two distinct species groups included in the genus. On the basis of the larvae examined, *Eanus* is an isolated genus, readily distinguished by the following characters: Dorsum of ninth abdominal segment (fig. 40, *d*, *e*) strongly convex, and without raised lateral margins; urogomphus (*ur*) undivided, blunt, and with a strongly sclerotized bar on inner aspect; abdominal pleurites absent or practically so (fig. 40, *b*, *c*); abdominal mediotergites (*mtg*, fig. 40, *b*) with very faint, short impressions, and with only 3 prominent unpaired setae in the posterior transverse row.

Eanus larvae are pale yellow; up to 18 mm. in length; with inconspicuous sculpture. Ninth abdominal segment with small caudal notch, and distance between pleural area and caudal notch about one-fifth length of segment, exclusive of urogomphi. Nasale of 1 sharp tooth. Eyes present; bordered by 2 unpaired setae. Two unpaired lateroepicranial setae on each gena. Gula extremely narrow, area practically closed posteriorly. One "sensory" appendix on second segment of antenna. Mandible (fig. 40, *a*) very robust with toothlike expansion of dorsal margin of inner face of distal half. Presternum of prothorax divided, the posterior median piece being very small. Mesothorax and metathorax with faint but definite impressions on mediotergites, and without spinelike setae on episterna.

Material used in study of the genus.—*E. decoratus* (Mannerheim): Eleven examples were examined, including the exuviae of three reared specimens. All were from the province of Quebec and the reared adults were identified by W. J. Brown, of Ottawa. (C.N.C.) Material identified through rearing is listed below:

1; Mount Lyell, Gaspé County, Quebec, 1,500 ft.; (no date); adult found emerged on Oct. 1, 1934; C. C. Smith. (C.N.C.)

2; Cascapedia River, Quebec; adults emerged Sept. 7 and Sept. 20, 1935; M. L. Prebble. (C.N.C.)

E. costalis (Paykull) (?): One larva from Suomussalmi, Finland, was all the material available for examination. This was an unidentified specimen that is believed to be *E. costalis* because of its morpho-

logical similarity to *E. decoratus* larvae and because *E. costalis* inhabits Finland. On the basis of adult characters, Brown (1930) reported these two species to be very closely related. The larva examined is the property of Prof. U. Saalas, Helsinki, Finland.

Genus MELANACTES LeConte

MELANACTES DENSUS LeConte

FIGURE 40, *f*

Melanactes densus is the only species of this genus that is known in the larval stage. It is a western species, but the natural habitat of the larva is unknown, the only specimen available for examination being reared from eggs laid in captivity.

On the basis of larval characters this species is a typical member of the tribe Lepturoidini and should not be separated into a distinct tribe as arranged by Leng (1920). Superficial resemblances are found in the larvae of *Hemicrepidius, Crepidomenus,* and *Cryptohypnus,* but no closely related genera are known. The larva of *M. densus* (fig. 40, *f*) is readily distinguished by its large size, absence of eyes, setal and sculptural patterns, shape of the caudal notch, and the urogomphi in which the inner prongs are small and the outer prongs very long and corniform. The larva hitherto regarded by some writers as *Melanactes piceus* (DeGeer), originally figured by Riley and reproduced by Blatchley (1910, p. 771, fig. 292), unquestionably is not a *Melanactes* larva or the larva of any other elaterid.

The larva examined was not fully distended, but measured 38 mm. in length and 4.75 mm. in breadth at 5 years of age. Fully distended mature larvae undoubtedly would exceed 40 mm. Dorsum golden brown; venter paler; lateral membranes large, creamy white. Caudal notch large, transverse. Urogomphi short, robust, bifid; prongs corniform, with sharp upturned tips; outer prongs 3 to 4 times as long as inner prongs. Ninth abdominal segment without a mediodorsal groove, but with a shallow subcircular depression bearing 2 faint, short, paramedian impressions; 4 widely separated setae on central dorsal area, posterior setae being longer; 3 blunt "teeth" on each lateral margin of dorsal plate; tergite continues uninterruptedly on posterior ventral surface for a distance approximating one-eighteenth total length of segment exclusive of urogomphi; sternum large, consisting of 2 sclerites separated anteriorly by a narrow median suture. Nasale of 1 tridentate tooth, median denticle slightly larger than lateral denticles. Frontoclypeal region broadly rounded posteriorly. One small dorsal posteroepicranial seta just laterad to each side of posterior part of

frons. Eyes absent. With 4 setae surrounding each eye region. Two unpaired lateroepicranial setae on each gena. Gula short and narrow. One "sensory" appendix on second segment of antenna. Mandible with well-developed retinaculum. Presternum of prothorax undivided, but may be deeply incised laterally near apex, almost separating off a small, narrow, posterior median sclerite. Mesothorax and metathorax with prominent long impressions, up to 7 spinelike setae on each episternum. Abdominal mediotergites with impressions reaching to middorsal suture; first to seventh segments with conspicuous transverse rugae, eighth segment with pits more nearly circular; 1 anterior mediotergal seta present on each mediotergite; conspicuous setae unpaired on anterior part of segments, but approaching a semipaired arrangement in posterior transverse row. Abdominal pleurites large, decreasing in size from first to eighth segments. Spiracles noticeably widened anteriorly, subpyriform; situated in anterior part of segments.

Material used in study.—The only specimen available for examination was a 5-year-old larva received through the courtesy of Dr. W. H. Anderson, U. S. Bureau of Entomology and Plant Quarantine, Washington, D. C.

1; Huntington Beach, Calif.; reared from eggs that hatched June 3, 1935; M. W. Stone. (U.S.N.M.)

SUMMARY OF TAXONOMIC RELATIONSHIPS

In the Lepturoidini, relationships based upon larval characters agree closely with those founded upon careful study of the adults. Recognized subspecies are morphologically indistinguishable in the larval stage, closely allied species appear to be more readily distinguished as adults than as larvae, as evidenced by the species of *Ludius* included in the *cupreus* group and the *aeripennis* group; but group relationships are revealed as clearly by the larvae as by the adults. The evidence from larval studies should be considered in taxonomic revisions. However, such evidence must be used with exceeding care, because it is based upon a very small proportion of the existing species.

Rightly or wrongly, at the beginning of this study the type species were looked upon as the ultimate criteria for the determination of generic status. It was believed that any given larva could be classified to genus by comparing it with genotype material. In practice this proved futile, especially for large genera, because only a very small proportion of the available species of each large "genus" bore evident close relationship to the genotype. The supraspecific unit that stood out clearly as a measure of relationship was the "species group,"

DIAGRAM OF GENERAL RELATIONSHIPS BETWEEN LEPTUROIDINE GENERA AND "SPECIES GROUPS" OF LUDIUS

Species above the broken transverse line have the nasale single-pointed; species below this line have the nasale triple-pointed, except in *Limonius pilosus* (Leske). Genera in parentheses have the urogomphi simple; all others have the urogomphi bifid. The spacing suggests the degree of relationship, and possible annectant groups are indicated by connecting lines.

	CAUDAL NOTCH LARGE	CAUDAL NOTCH SMALL
PROSTERNUM DIVIDED (nasale unidentate)	II rotundicollis bipustulatus propola inflatus aeripennis triundulatus	I *(EANUS)* appressus cupreus
PROSTERNUM DIVIDED (nasale tridentate at tip)	semivittatus fallax edwardsi nitidulus *CRYPTO-HYPNUS* *CREPI-DOMENUS*	sjaelandicus
PROSTERNUM UNDIVIDED (nasale tridentate)	IV *MELANACTES* *HEMICREPIDIUS*—*ATHOUS* (cucullatus) (undulatus) (mutilatus) divaricatus *(HYPNOIDUS)*	III pyrrhos limoniiformis resplendens *ELATHOUS*—*LIMONIUS* *ATHOUS* *LEPTUROIDES* (vittatus) (rufifrons)

of which several to many were apparent within each of the larger genera as recognized in the current taxonomic literature. In effect, each genotype was representative of but one "species group."

Some of the larger genera are too complex to be adequately characterized. This is particularly true of *Ludius* and *Athous* and to a lesser degree of *Limonius*. On the basis of the material studied, the following genera appear to be sufficiently homogeneous to permit of characterization: *Crepidomenus, Cryptohypnus, Hypnoidus, Eanus, Elathous, Lepturoides, Hemicrepidius,* and *Melanactes*. However, larvae of only one to five species were available for each of these genera and insufficient representation may account for this apparent homogeneity.

In general, the taxonomic value of any character or set of characters changes from one "species group" to another. However, throughout the tribe studied certain characters have maintained a high ordinal value. Simple urogomphi and bifid urogomphi have not been found within the same genus; and the type of caudal notch, the general type of prosternum, and the general type of nasale have varied comparatively little between species of the same "species group." Accordingly, these are regarded as primary group characters, their relative importance being as in the order stated. On the basis of these characters the general relationships between the "species groups" of *Ludius* and the other lepturoidine genera are charted on page 191.

THE GENUS LUDIUS

The "species groups" of *Ludius* that have been erected on the basis of larval characters agree closely with those independently established by Brown (1935, 1936, 1939), who studied the adults of the American species. Where adequate larval material was available, Brown's groups were invariably substantiated, but where the larvae of only a very few species were known or where the material was not suitable for a complete examination, the larval study suggested fewer groups than Brown had erected. The writer agrees completely with the following statement (Brown, 1935a, p. 1): "The genus *Ludius,* as now recognized in the American literature, is not a true genus in any natural sense, but is, rather, a heterogeneous group of species the natural affinities of which are not known." Similar conclusions have been reported by Blatchley (1910, p. 763) and by Van Dyke (1932, pp. 389-390), who studied the adults, and by Henriksen (1911, p. 258), who described the larvae of seven species.

Brown has done much toward establishing the natural affinities of many of the species now included in the genus. However, no proposals have yet been made for reducing the genus to a more homogeneous assemblage. The larval record is much too incomplete to form a basis for sound revision. In fact, since only 10 percent of the species are known in the larval stage, it is dangerous even to attempt an appraisal of specific relationships. However, a brief appraisal of the larval evidence is presented with the hope that it might encourage further efforts in this direction.

The 44 species of *Ludius* studied have been arranged into 17 distinct "species groups," some groups being represented by a single species. For purposes of identification, these groups are best considered in the four major sections (I, II, III, IV) shown on page 191. However, the natural affinities of *Ludius sjaelandicus* (Muller) are believed to lie nearer to several species in section III than to the other species in section I. Within section II some of the "species groups" are very closely related, e.g., *inflatus* and *aeripennis, semivittatus* and *edwardsi;* whereas *propola, triundulatus,* and *fallax* are not quite so closely allied; and *bipustulatus, rotundicollis,* and *nitidulus* are relatively isolated. In contrast, the *Ludius* species that fall in section III are not more closely related to one another than are the recognized genera *Elathous, Limonius, Athous* (pars), and *Lepturoides,* which also fall in that section.

The larval characters suggest that for taxonomic purposes the genus *Ludius* might be revised by making the following subdivisions (genera ?):

SUBDIVISION 1: the *cupreus* and *appressus* groups; the relationships of *appressus* (Randall) seem to lie with *cupreus.*

SUBDIVISION 2: all *Ludius* included in section II; the *nitidulus* group might form the nucleus of a distinct subdivision connecting with the genera *Cryptohypnus* and *Crepidomenus.*

SUBDIVISION 3: *L. divaricatus* (LeConte) and its allies; this is an isolated species without close affinities to any known group in the Lepturoidini.

SUBDIVISION 4: *L. sjaelandicus* (Muller) and allied species, if any exist.

SUBDIVISION 5: the *pyrrhos* group.

SUBDIVISION 6: the *limoniiformis* group.

SUBDIVISION 7: *L. resplendens* (Eschscholtz) and its allies; the possibility of removing *resplendens* to the genus *Elathous* warrants consideration.

Subdivisions 4 and 5 have a somewhat common bond in the unusual condition of the spiracles in the eighth abdominal segment, and in setal and sculptural characters. Likewise, subdivisions 4, 5, 6, and 7 all have the urogomphal prongs subequal and certain other characters in

common. However, the union of two or more of these groups produces an assemblage that cannot be adequately characterized to permit ready separation from the other genera included in section III of the diagram on page 191.

This attempt to reduce the genus *Ludius* to definable limits is merely suggestive. The larval record is too incomplete to provide the necessary perspective, but it might supplement the evidence from adult studies. There are two alternatives to the suggested subdivisions given above: make every "species group" a new genus, or leave the genus in its present indefinable state. From the purely phylogenetic viewpoint, it is doubtful if genera are completely definable. Therefore group limits for taxonomic purposes are very difficult to draw.

Species seem to be well defined in those parts of the genus that Brown has revised. His species have been substantiated wherever adequate larval material was available for study. However, very detailed examination frequently was necessary to discover the separating characters of closely allied forms. Brown's species concept appears to be valid, but any narrower concept could not be supported by larval evidence. As more material becomes available, it is quite possible that larval characters will not be found to separate all species that Brown has recognized. Such a result can be expected, since distinctions that are evident in the definitive adults might be obscured in the developmental stages.

Ludius rotundicollis (Say), as currently recognized, appears to include more than one species. The larvae from the eastern States and those from the western States are morphologically distinct and, therefore, should be considered as distinct species.

The Athous Complex

In contrast to the genus *Ludius*—which has been allowed to develop into an indefinable assemblage—other parts of the Lepturoidini have been separated into smaller, closely related genera. Thus *Elathous, Hemicrepidius,* and *Lepturoides* are very closely allied to the genus *Athous* as recognized at present, but *Athous* itself is polymorphic. As illustrated on page 191, sections III and IV, *Athous* consists of two main parts which are less closely related to each other than to other established genera. The failure of European workers to recognize the genus *Hemicrepidius* in their fauna is due to its similarity to *Athous*. The European *Athous niger* (Linnaeus) and its allies are typically *Hemicrepidius*. Whether *Hemicrepidius*

should be recognized as a genus or merely as one or more "species groups" under *Athous* is open to question. On the basis of larval characters *Hemicrepidius* is not more distinct from *Athous* than are the "species groups" of *Athous* (enumerated in section IV) from one another. The other half of *Athous*, as represented by the *vittatus* and *rufifrons* groups, is closely allied to *Elathous* and *Lepturoides*. In fact, *Lepturoides* is not more distinct from these groups of *Athous* than these are from each other. *Elathous*, on the other hand, appears to fill the gap between *Limonius* and *Athous* (pars) and probably should be retained as a distinct genus. The rather fragmentary larval record suggests, therefore, that *Athous* be revised into two genera, as in sections III and IV and that *Hemicrepidius* might be included with the one part and *Lepturoides* with the other, or these retained as distinct genera as at present. *Elathous* should remain as a genus.

The writer is fully in accord with Van Dyke (1932, p. 356), who states that *Elathous bicolor* (LeConte) should not be included with the genus *Leptoschema* Horn. On the basis of larval characters *Leptoschema* belongs in the subfamily Elaterinae.

THE GENUS LIMONIUS

Limonius is less complex than *Ludius* and *Athous*. This is shown on page 191, the genus being confined to section III. However, the larvae exhibit considerable polymorphism, mainly in characters of the mandibles, nasale, and urogomphi. At present, it would appear premature to erect genera on these characters. However, if any revision of the genus were to be made on the basis of larval characters the following subdivisions are suggested:

SUBDIVISION 1: the *aeneoniger* group; these larvae are well characterized by the mandibles, nasale, subnasale, and small outer urogomphal prongs.

SUBDIVISION 2: *L. pilosus* (Leske) and its allies; the single-pointed nasale, the subnasale, and the mandibles isolate this larval type.

SUBDIVISION 3: includes all remaining species of *Limonius* known in the larval stage. This subdivision brings together rather diverse forms, but the chief difference is that *pectoralis, aeger,* and *confusus* (?) all have very small outer prongs whereas the members of the *canus* group have well-developed outer prongs. However, this character does not appear to have high ordinal value, especially since *aeger* is obviously related to the *canus* group through several other characters.

THE GENERA HYPNOIDUS AND CRYPTOHYPNUS

There has been a tendency in recent years for taxonomists to suppress the genus *Cryptohypnus* and to place its species under

Hypnoidus. According to Hyslop (1921), *Elater riparius* Fabricius was designated by Westwood in 1840 as the type of *Hypnoidus* Stephens; in 1859 the same species was designated by Thompson as the type of *Cryptohypnus.* If *riparius* be used as the type of *Hypnoidus,* then species such as *H. dubius* (Horn), *H. musculus* (Eschscholtz) and *H. maritimus* Curtis must be placed in a distinct genus. On the basis of larval characters, *riparius* and its allies definitely are not congeneric with *H. dubius* and its allies.[16] The latter group have simple urogomphi, a 1-segmented galea, a very characteristic mandible, the prosternum undivided, and several other characters which separate them widely from the species which commonly have been placed in *Cryptohypnus.*

THE TRIBE LEPTUROIDINI

Without a careful study of the larvae of other tribes of the Pyrophorinae, the writer cannot appraise properly the status of the Lepturoidini. However, it would appear to be a reasonably well-characterized group. *Crytohypnus* and *Melanactes,* which Leng (1920) placed in the tribes Hypnoidini and Melanactini, respectively, properly belong in the Lepturoidini. The most aberrant genera are *Eanus* and *Hypnoidus.* These are extreme forms and appear to be quite isolated within the tribe. It may be that larvae eventually will be found to link these genera more closely to the other Lepturoidini.

LIST OF SPECIES STUDIED

This list is designed to serve two main purposes: First, as an index to the principal descriptive sections on each species; and second, as a ready reference to the continental representation and the general reliability of the material used. The genera are listed alphabetically and the species alphabetically under each genus. The following symbols are used: Aus. for the continent of Australia; Eur. for Eurasia; N.A. for North America; * for species of which reared adults and their larval exuviae were available to the writer; ≠ for species whose identification was known to be or believed to be based upon rearing, but reared adults could not be obtained for confirmation; x for species whose identification was believed to be fairly reliable, but not based upon rearing as far as was known; and o for species whose identification was very uncertain. Symbols in paren-

[16] Support of this conclusion is given in a recent critical review based upon adult characters. (Vide M. C. Lane, "Some Generic Corrections in the Elateridae, II," Proc. Ent. Soc. Washington, vol. 50, No. 8, pp. 221-223, November 1948.)

theses indicate that larval material was not available to the writer and all knowledge of such species was obtained from the literature.

	Species	Distribution	Page
*	*Athous brightwelli* (Kirby)	N.A.	173
*	" *cucullatus* (Say)	N.A.	175
#	" *haemorrhoidalis* (Fabricius)	Eur.	171
x	" *hirtus* (Herbst)	Eur.	180
#	" *mutilatus* Rosenhauer	Eur.	174
*	" *niger* (Linnaeus)	Eur.	180
*	" *nigropilis* Motschulsky	N.A.	175
#	" *pallidipennis* Mannerheim	N.A.	173
*	" *rufifrons* (Randall)	N.A.	173
*	" *scapularis* (Say)	N.A.	175
#	" *subfuscus* (Müller)	Eur.	172
#	" *undulatus* (DeGeer)	Eur. & N.A.	177
#	" *villosus* (Geoffroy)	Eur.	177
#	" *vittatus* (Fabricius)	Eur.	172
#	*Crepidomenus queenslandicus* Blair	Aus.	181
*	*Cryptohypnus abbreviatus* (Say)	N.A.	185
*	" *sanborni* Horn	N.A.	184
#	" *funebris* Candeze	N.A.	185
*	" *nocturnus* (Eschscholtz)	N.A.	184
#	" *riparius* (Fabricius)	Eur.	184
x	*Eanus costalis* (Paykull)	Eur.	188
*	" *decoratus* (Mannerheim)	N.A.	187
*	*Elathous bicolor* LeConte	N.A.	167
*	*Hemicrepidius bilobatus* (Say)	N.A.	180
#	" *carbonatus* (LeConte)	N.A.	180
*	" sp., near *carbonatus* (LeConte)	N.A.	180
*	" *hemipodus* (Say)	N.A.	180
*	" *memnonius* (Herbst)	N.A.	180
*	*Hypnoidus dubius* (Horn)	N.A.	187
x	" *maritimus* Curtis	Eur.	187
*	" *musculus* (Eschscholtz)	N.A.	187
*	*Lepturoides denticornis* (Kirby)	N.A.	169
o	" *fulvus* (Motschulsky)	N.A.	169
#	" *linearis* (Linnaeus)	Eur.	169
*	*Limonius aeger* LeConte	N.A.	163
#	" *aeneoniger* (DeGeer)	Eur.	159
o	" *anceps* LeConte	N.A.	164
#	" *californicus* (Mannerheim)	N.A.	164
#	" *canus* LeConte	N.A.	164
o	" *confusus* LeConte	N.A.	162
#	" *consimilis* Walker	N.A.	159
#	" *dubitans* LeConte	N.A.	164
x	" *ectypus* (Say)	N.A.	164
*	" sp., near *ectypus* (Say)	N.A.	164
o	" *occidentalis* Candeze	N.A.	164
*	" *pectoralis* LeConte	N.A.	161
x	" *pilosus* (Leske)	Eur.	160
#	" *subauratus* LeConte	N.A.	164

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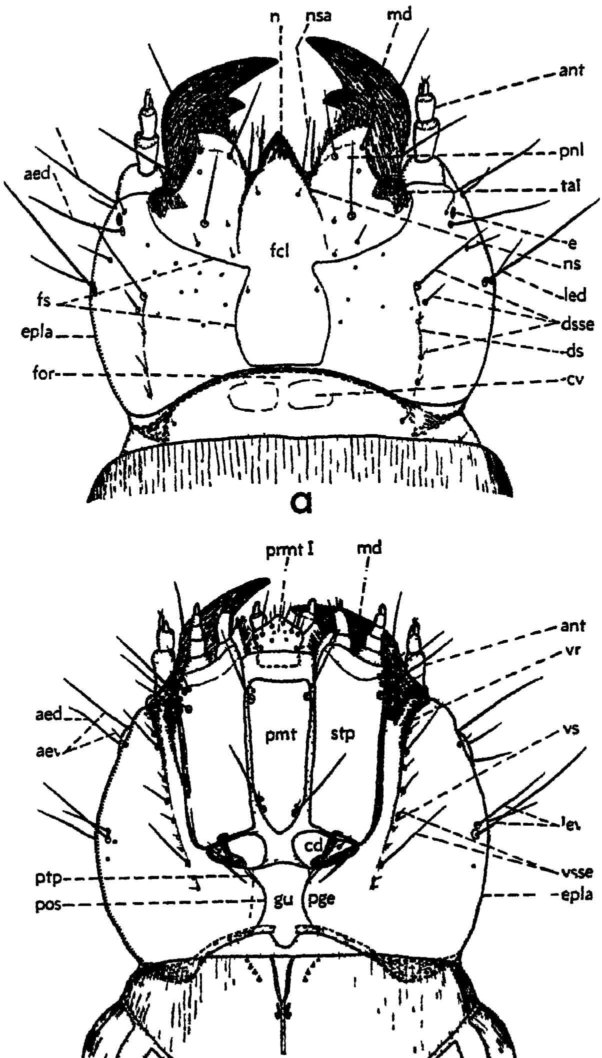

FIG. 1.—*Ludius aeripennis destructor* Brown.
a, head, dorsal view; *b*, head, ventral view

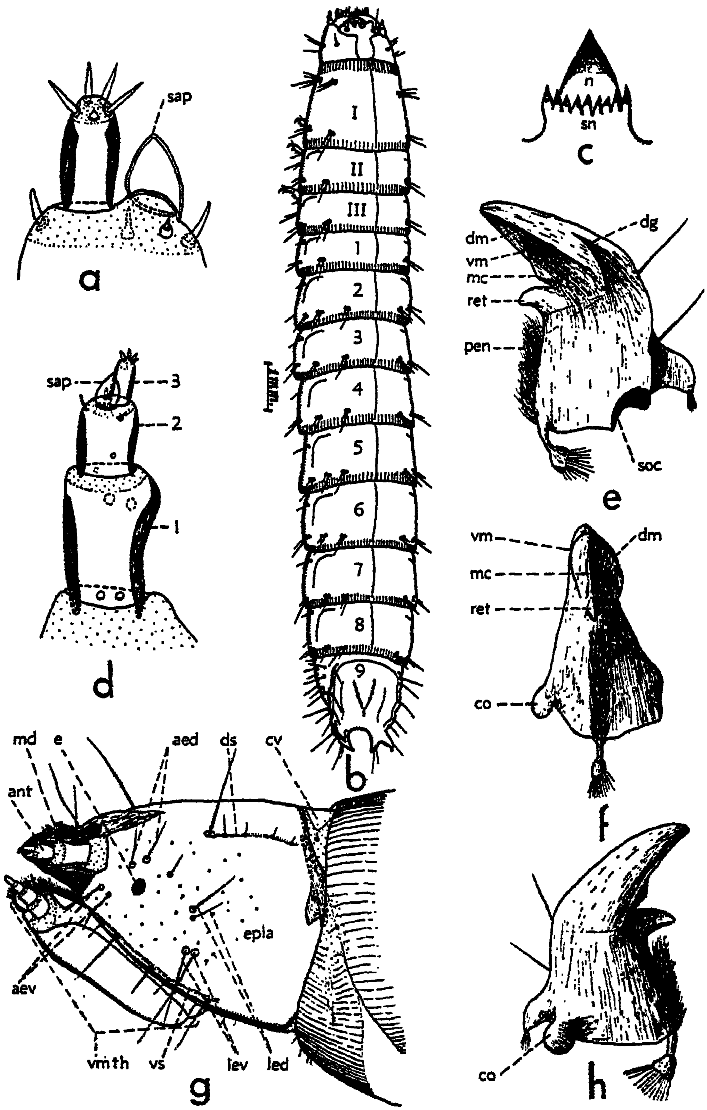

FIG. 2.—*Ludius aeripennis destructor* Brown.

a, third segment and tip of second segment of left antenna, mediodorsal view; *b*, whole larva, dorsal view; *c*, nasale and subnasale, ventral view; *d*, left antenna, ventral view; *e*, right mandible, dorsal view; *f*, right mandible, medial view; *g*, head, lateral view; *h*, right mandible, ventral view.

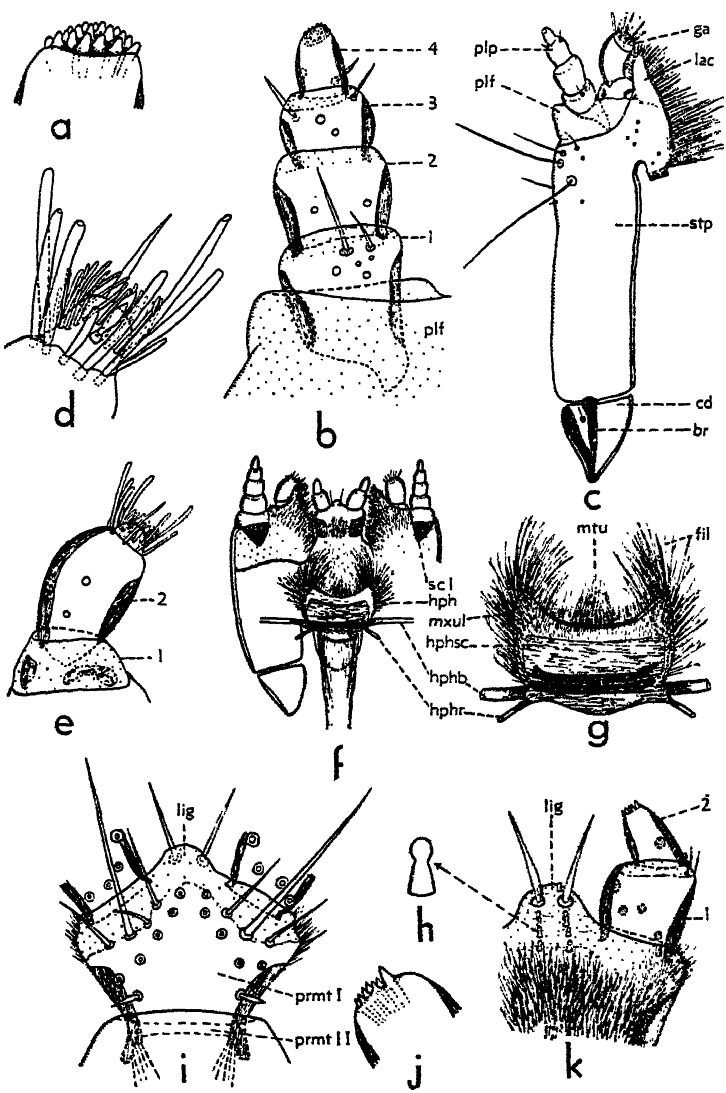

FIG. 3.—*Ludius aeripennis destructor* Brown.

a, tip of maxillary palpus, dorsal view (oil immersion); *b*, maxillary palpus, medioventral view; *c*, right maxilla, medioventral view; *d*, tip of galea, dorsal view (oil immersion); *e*, right galea, medioventral view; *f*, preoral cavity with hypopharynx in situ, dorsal view; *g*, posterior portion of hypopharynx, dorsal view; *h*, "sensory" peg from dorsal surface of ligula; *i*, first prementum and second prementum, ventral view; *j*, tip of labial palpus, dorsal view (oil immersion); *k*, first prementum, dorsal view.

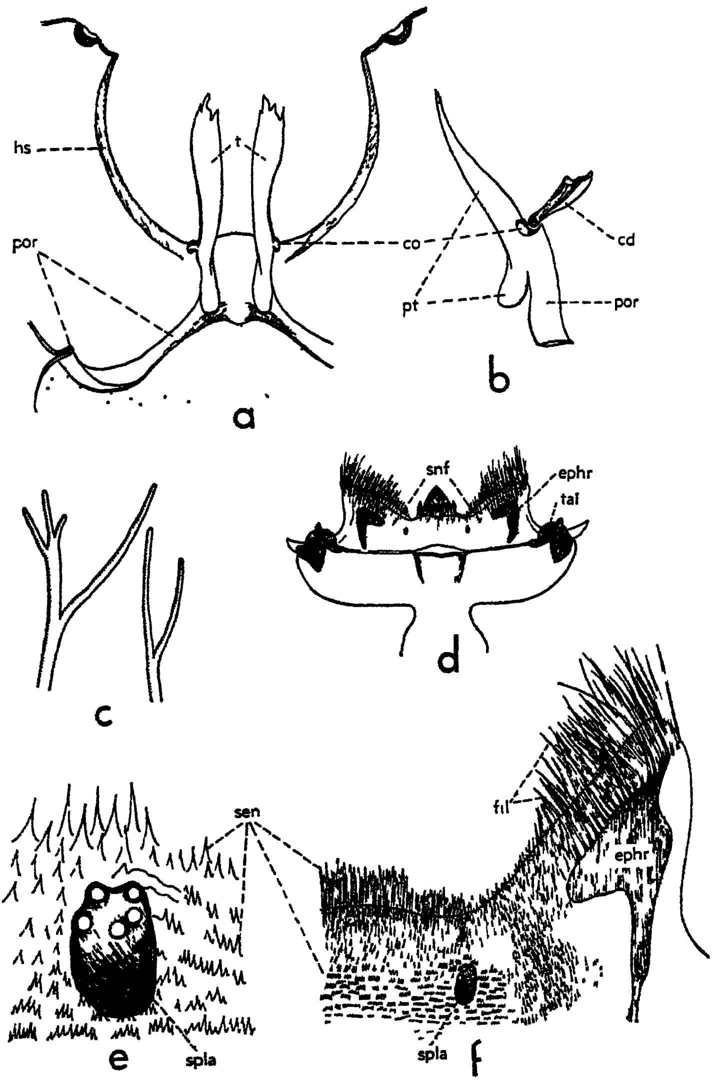

FIG. 4.—*Ludius aeripennis destructor* Brown.

a, tentorium, in situ, dorsal view (semidiagrammatic); *b*, right half of tentorium, lateral view (semidiagrammatic); *c*, branching filaments from hypopharynx; *d*, dorsal aspect of preoral cavity; *e*, "sensory" plate and surrounding sensilla on subnasal flap (oil immersion); *f*, left half of "subnasal flap."

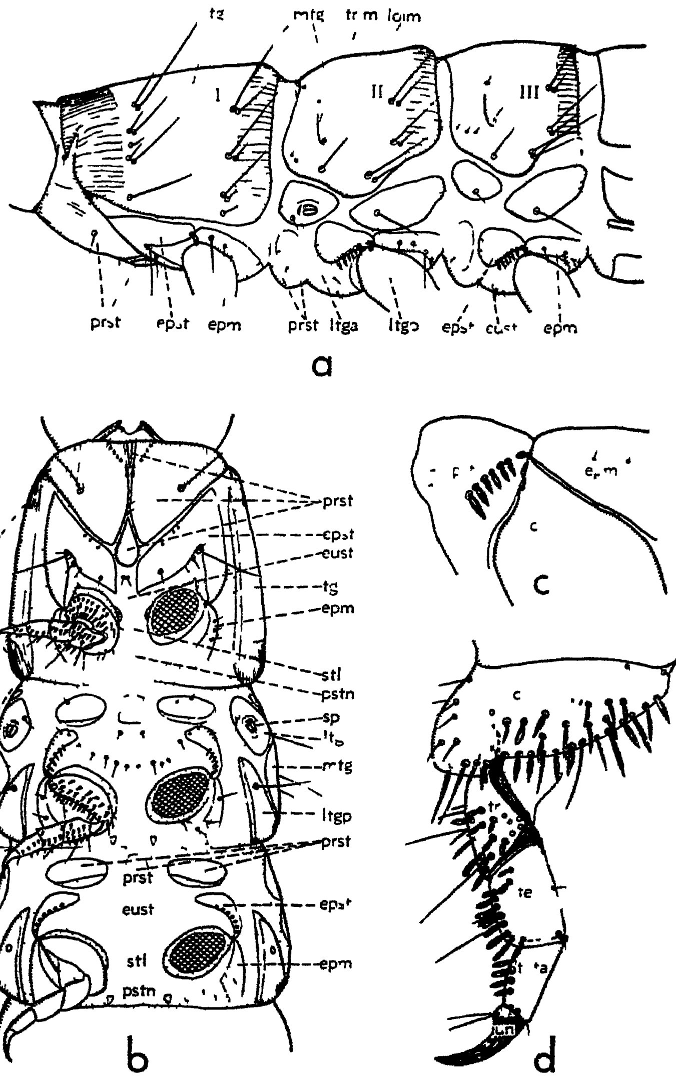

FIG. 5.—*Ludius aeripennis destructor* Brown

a, thorax, lateral view; *b,* thorax, ventral view (left legs removed; setae omitted from metathorax); *c,* episternum of mesothorax, lateral view, to show spinelike setae; *d,* left leg of mesothorax, anterior aspect.

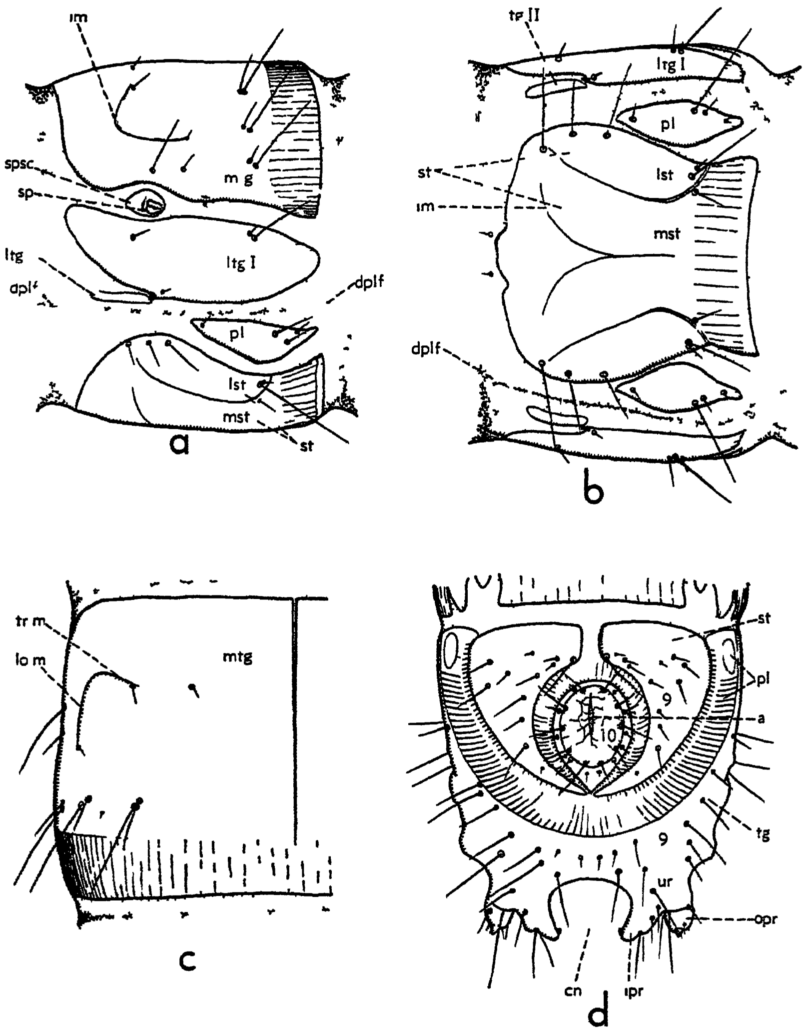

FIG 6—*Ludius aeripennis destructor* Brown

a, fourth abdominal segment lateral view, *b* fourth abdominal segment, ventral view, *c*, mediotergite of fourth abdominal segment, dorsal view, *d*, ninth and tenth abdominal segments, ventral view

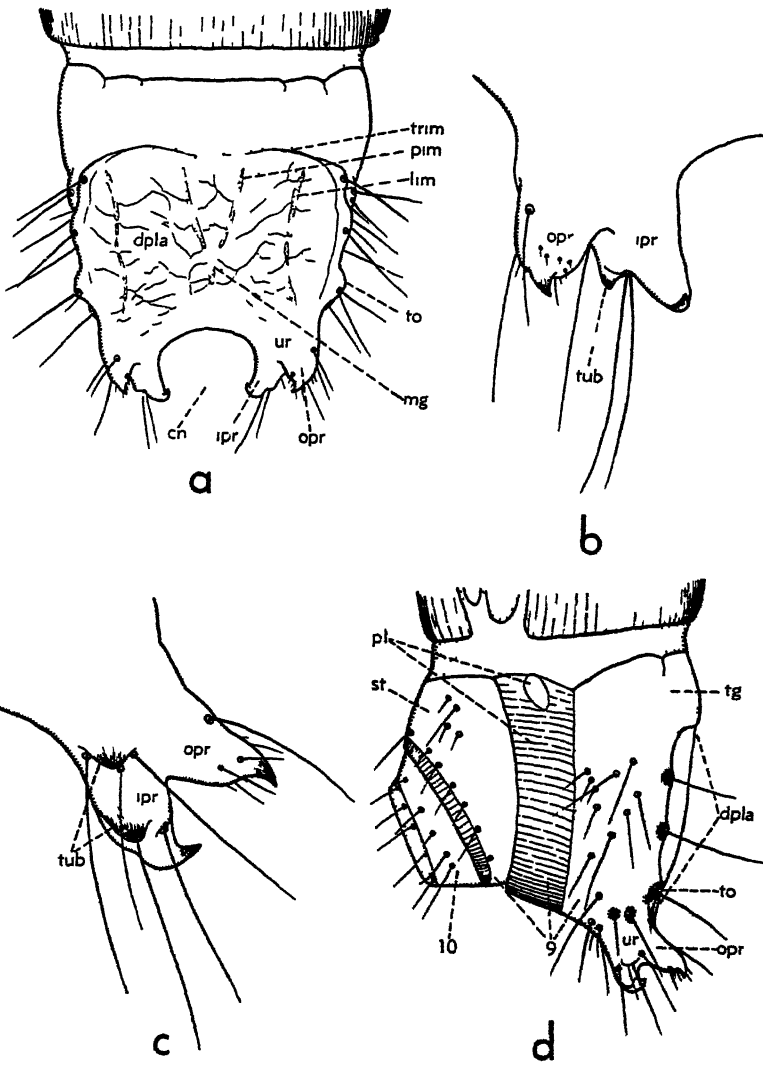

FIG 7—*Ludius aeripennis destructor* Brown

a, ninth abdominal segment, dorsal view, *b,* left urogomphus dorsal view *c* left urogomphus, lateral view, *d,* ninth and tenth abdominal segments, lateral view

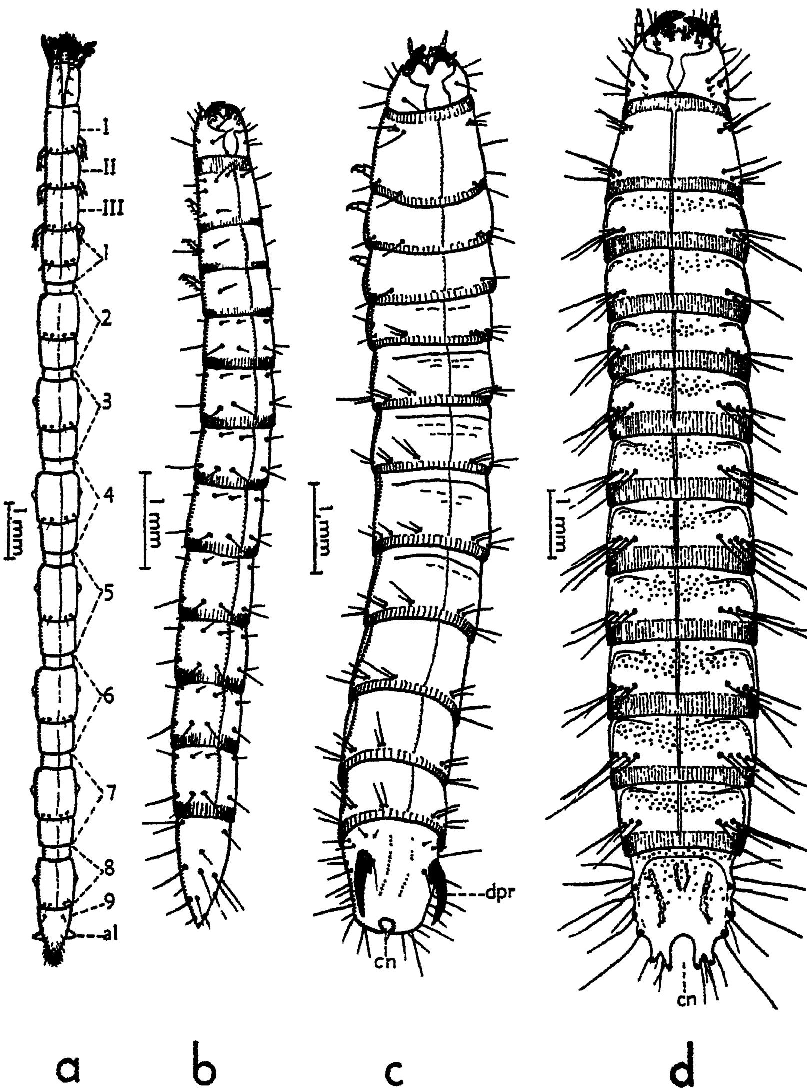

FIG. 8.—Representatives of subfamilies.

a, Cardiophorus sp., larva, dorsal view; subfamily Cardiophorinae. *b, Dalopius parvulus* Brown, larva, dorsal view; subfamily Elaterinae. *c, Oestodes tenuicollis* (Randall), larva, dorsal view; subfamily Oestodinae. *d, Ludius tessellatus* (Linnaeus), larva, dorsal view; subfamily Pyrophorinae.

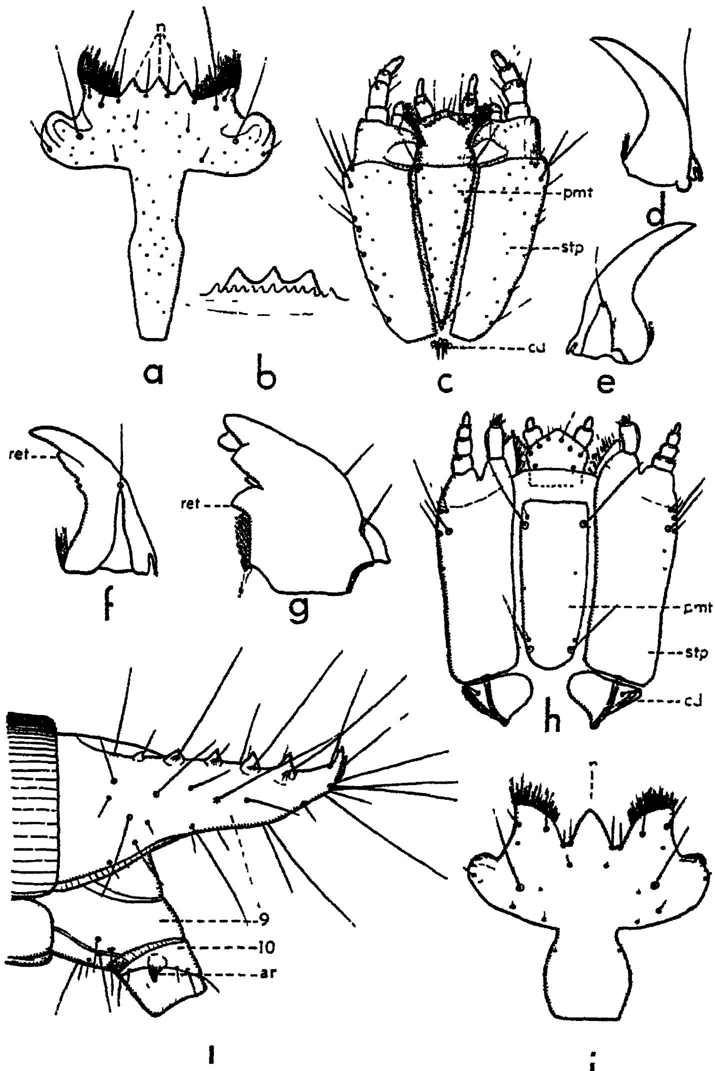

FIG. 9.—*Aeolus, Hypnoidus, Limonius,* and *Ludius.*

a-e, i, Aeolus mellillus marginicollis (Horn): *a,* frontoclypeal region, dorsal view; *b,* nasale and subnasale, ventral view; *c,* ventral mouthparts, ventral view; *d,* left mandible, ventral view; *e,* left mandible, dorsal view; *i,* ninth and tenth abdominal segments, lateral view. *f, Hypnoidus dubius* (Horn): right mandible, dorsal view. *g, Limonius aeneoniger* (DeGeer): right mandible, dorsal view. *h, j, Ludius aeripennis destructor* Brown: *h,* ventral mouthparts, ventral view; *j,* frontoclypeal region, dorsal view.

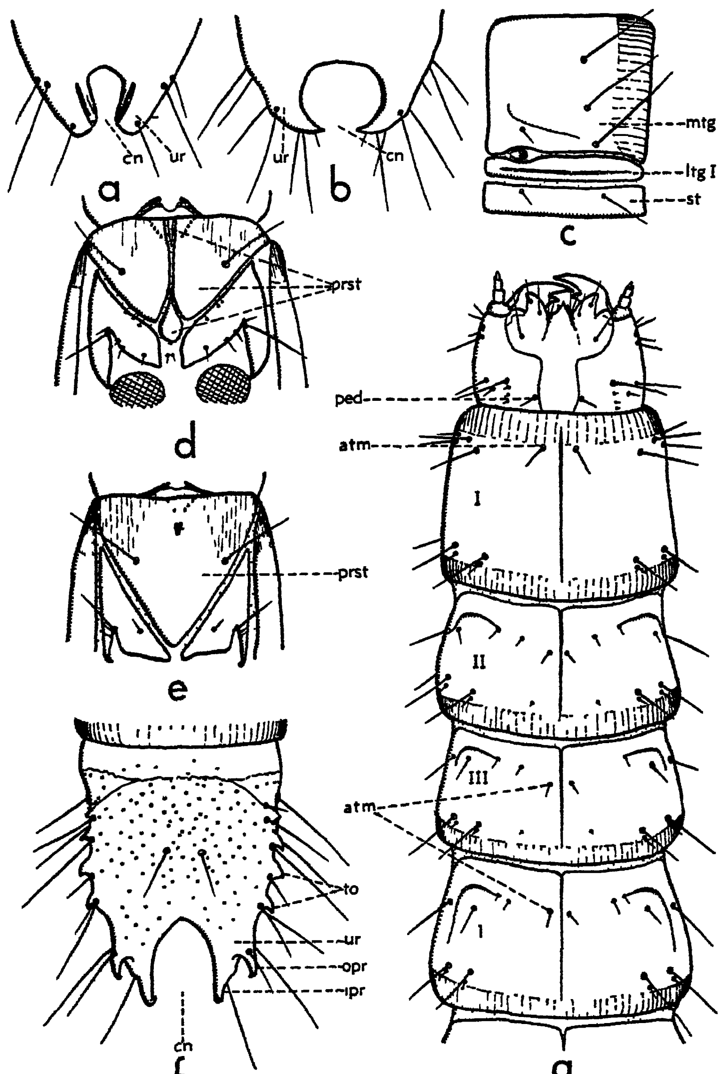

FIG. 10.—*Eanus, Hypnoidus, Ludius, Limonius, Crepidomenus* and *Cryptohypnus*.

a, c, Eanus decoratus (Mannerheim): *a*, urogomphi, dorsal view; *c*, third abdominal segment, lateral view. *b, Hypnoidus dubius* (Horn): urogomphi, dorsal view. *d, Ludius aeripennis destructor* Brown: presternal area of prothorax, ventral view. *e, Limonius dubitans* LeConte: presternal area of prothorax, ventral view. *f, Crepidomenus queenslandicus* Blair: ninth abdominal segment, dorsal view. *g, Cryptohypnus nocturnus* (Eschscholtz): head, thorax, and first abdominal segment, dorsal view.

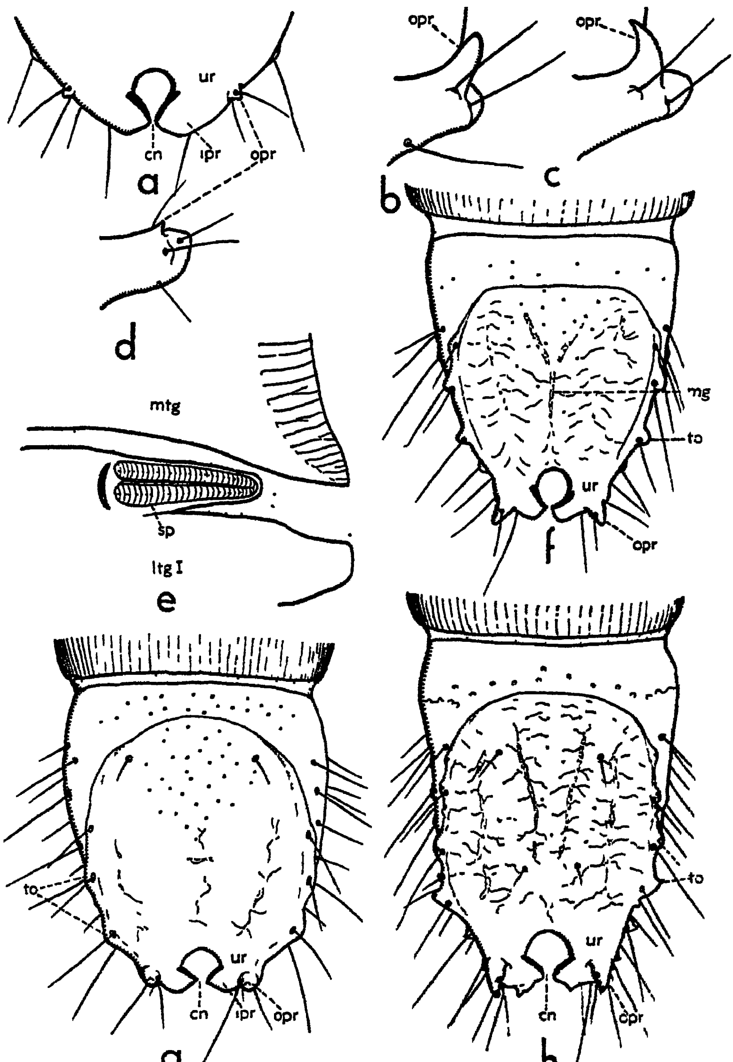

FIG. 11.—*Limonius, Ludius,* and *Elathous.*

a, Limonius aeneoniger (DeGeer): urogomphi, dorsal view. *b, f, Ludius resplendens aerarius* (Randall): *b,* left urogomphus, lateral view; *f,* ninth abdominal segment, dorsal view. *c, Elathous bicolor* (LeConte): left urogomphus, lateral view. *d, Limonius aeger* Leconte: left urogomphus, lateral view. *e, Ludius pyrrhos* (Herbst): spiracle of eighth abdominal segment. *g, Limonius ectypus* Say (?): ninth abdominal segment, dorsal view. *h, Ludius limoniiformis* (Horn) (?): ninth abdominal segment, dorsal view.

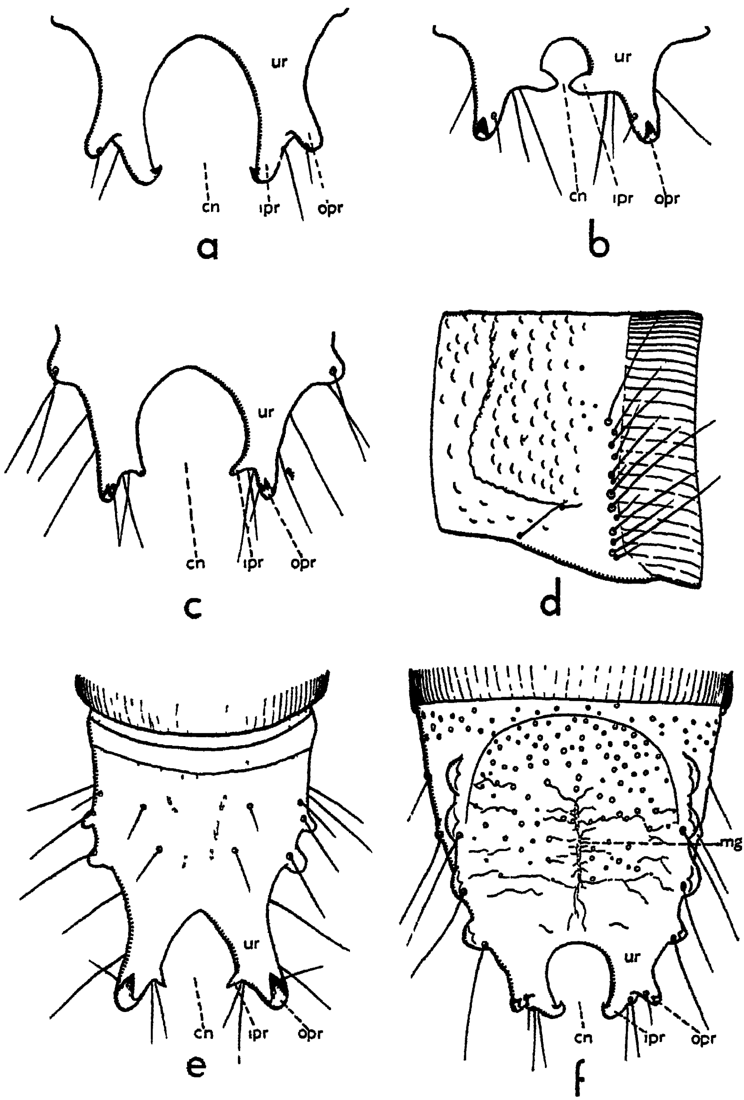

FIG. 12.—*Athous, Lepturoides, Hemicrepidius,* and *Ludius.*

a, Athous cucullatus (Say), urogomphi, dorsal view. *b, Lepturoides linearis* (Linnaeus), urogomphi, dorsal view. *c, Athous mutilatus* Rosenhauer, urogomphi, dorsal view. *d, Hemicrepidius* sp., mediotergite of fourth abdominal segment, lateral view. *e, Ludius divaricatus* (LeConte), ninth abdominal segment, dorsal view. *f, Hemicrepidius memnonius* (Herbst), ninth abdominal segment, dorsal view (drawn from a larval exuvium).

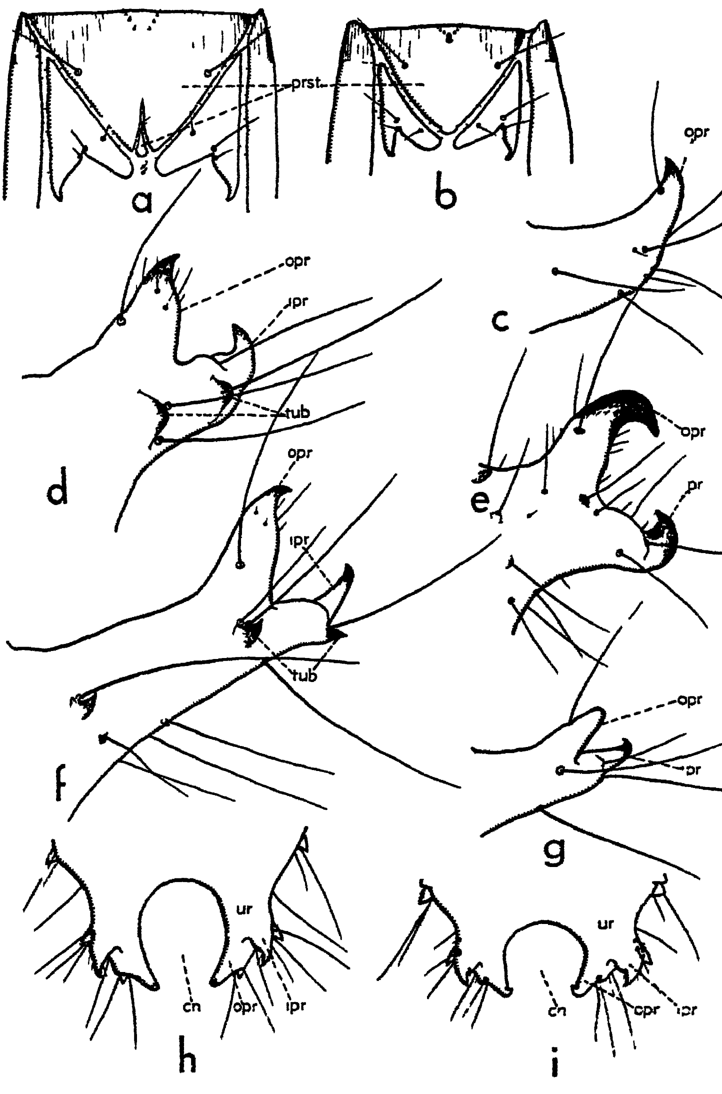

FIG. 13.—Species of *Ludius*.

a, Ludius nitidulus (LeConte): presternal area of prothorax, ventral view. *b, L. resplendens aerarius* (Randall): presternal area of prothorax, ventral view. *c, L. propola propola* (LeConte): left urogomphus, lateral view. *d. L. aeripennis destructor* Brown: left urogomphus, lateral view. *e, L. sexualis* Brown (?): left urogomphus, lateral view. *f, h, L. glaucus* (Germar): *f*, left urogomphus, lateral view; *h*, urogomphi, dorsal view. *g, L. triundulatus* (Randall): left urogomphus, lateral view. *i, L. pruininus* (Horn): urogomphi, dorsal view.

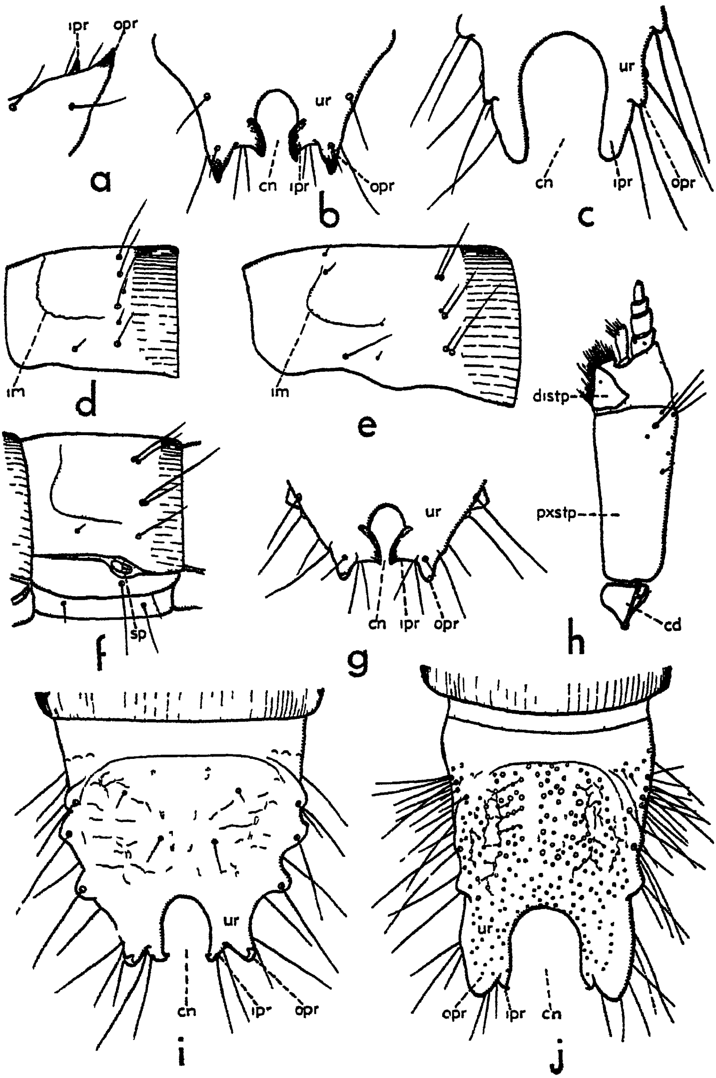

FIG. 14.—Species of *Ludius*.

a, b, Ludius appressus (Randall): *a,* left urogomphus, lateral view; *b,* urogomphi, dorsal view. *c, L. bipustulatus* (Linnaeus): urogomphi, dorsal view. *d, L. triundulatus* (Randall): mediotergite of fifth abdominal segment, lateral view. *e, L. aeripennis destructor* Brown: mediotergite of fourth abdominal segment, lateral view. *f, L. sjaelandicus* (Muller): eighth abdominal segment, lateral view. *g, L. kendalli* (Kirby): urogomphi, dorsal view. *h, L. cinctus* (Paykull): left maxilla, ventral view. *i, L. nitidulus* (LeConte): ninth abdominal segment, dorsal view. *j, L. rotundicollis* (Say) ("Western species"), ninth abdominal segment, dorsal view.

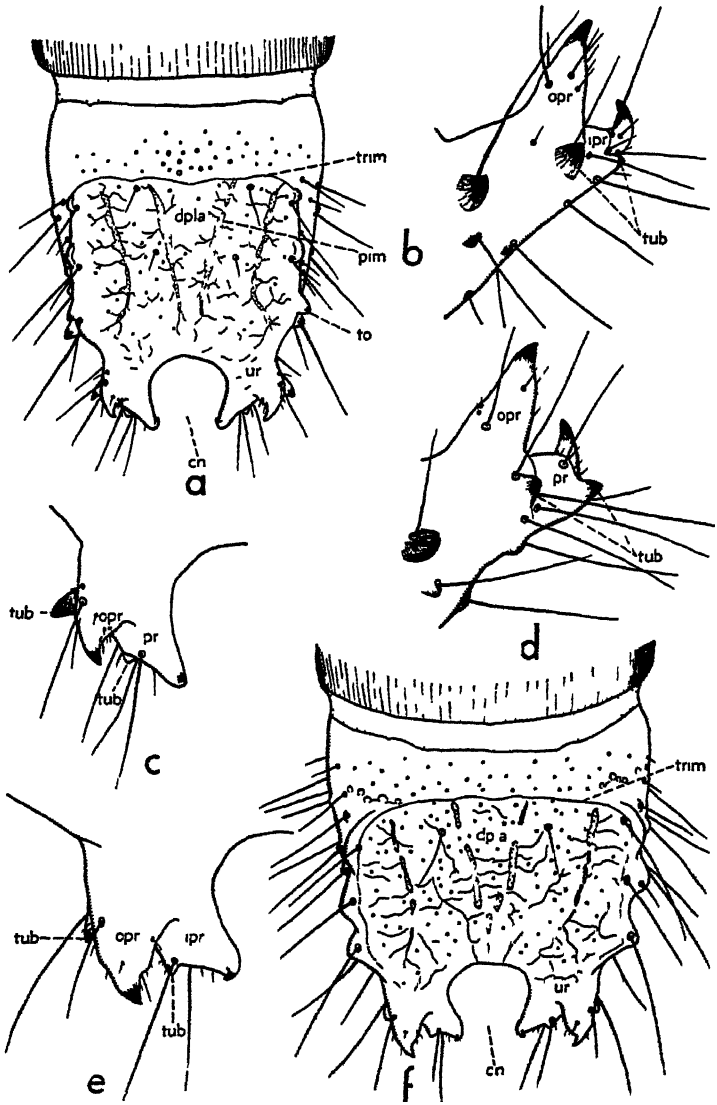

FIG. 15.—*Ludius aeripennis* group

a-c, Ludius pruininus (Horn): *a*, ninth abdominal segment, dorsal view; *b*, left urogomphus, lateral view; *c*, left urogomphus, dorsal view. *d-f, L. latus* (Fabricius): *d*, left urogomphus, lateral view; *e*, left urogomphus, dorsal view; *f*, ninth abdominal segment, dorsal view.

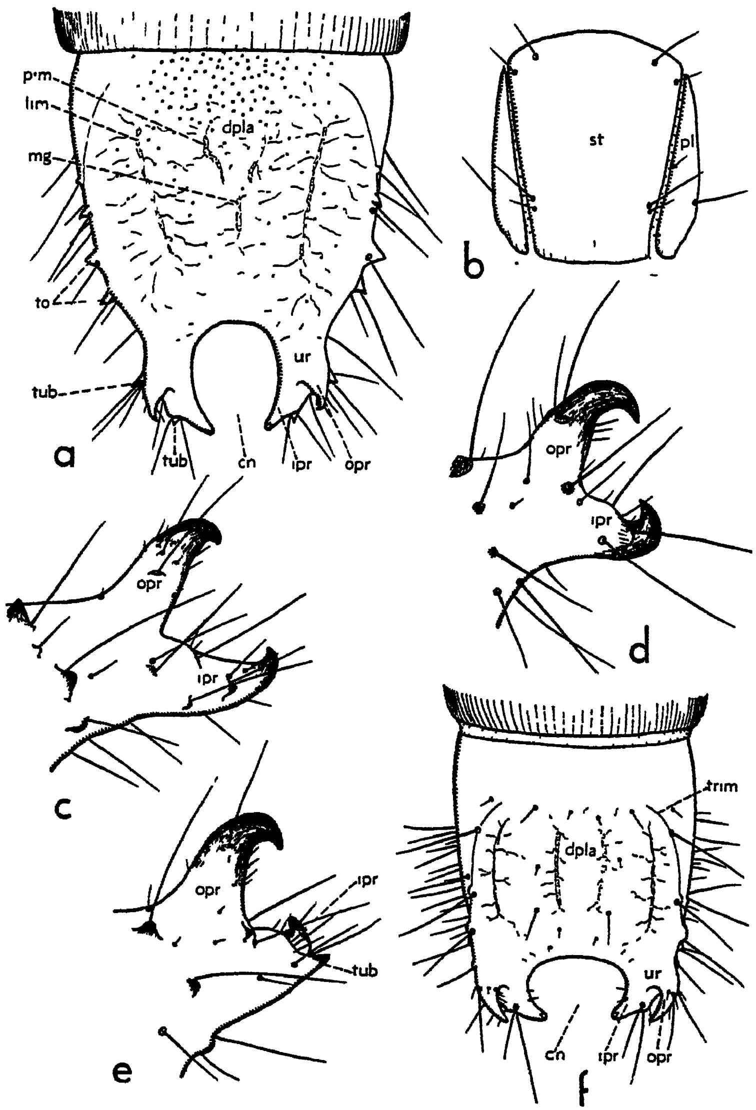

FIG. 16.—Species of *Ludius*.

a, *Ludius glaucus* (Germar): ninth abdominal segment, dorsal view. *b*, *e*, *L. semivittatus* (Say) (?): *b*, first abdominal segment, ventral view (semi-diagrammatic, the larva being much shrunken); *e*, left urogomphus, lateral view. *c*, *L. cruciatus festivus* (LeConte) (?): left urogomphus, lateral view. *d*, *f*, *L. sexualis* Brown (?): *d*, left urogomphus, lateral view; *f*, ninth abdominal segment, dorsal view.

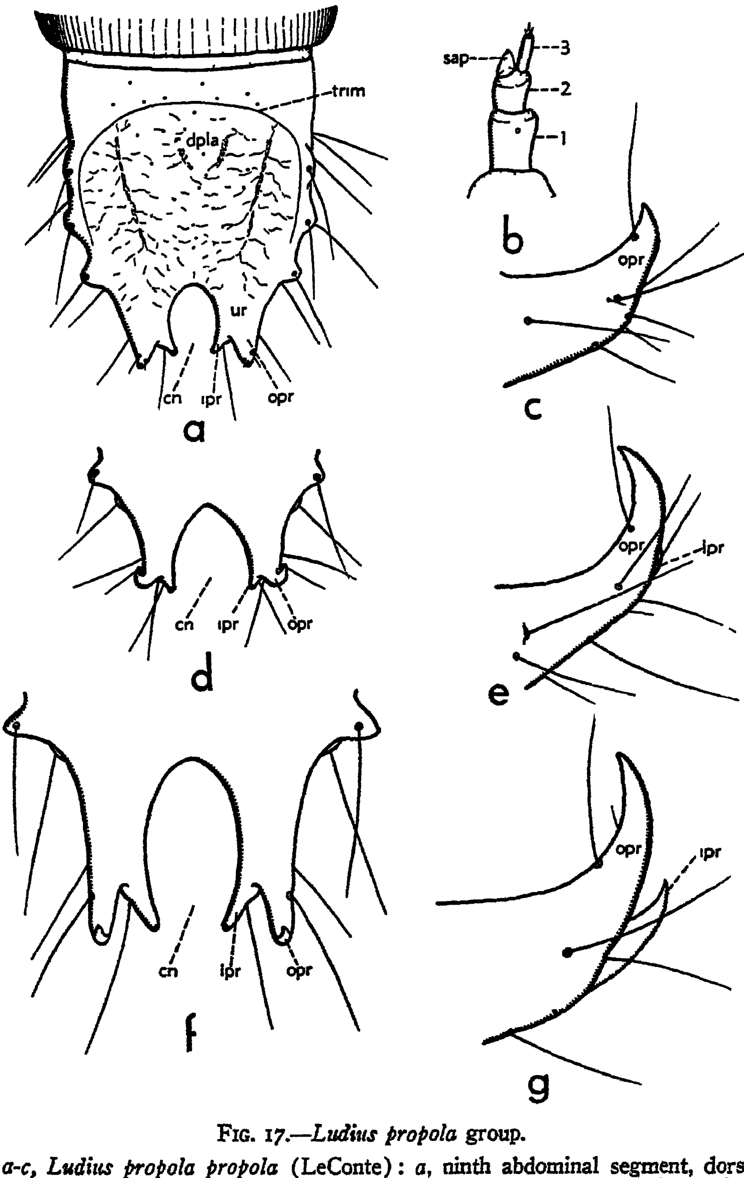

FIG. 17.—*Ludius propola* group.

a-c, Ludius propola propola (LeConte): *a,* ninth abdominal segment, dorsal view; *b,* right antenna, medial view; *c,* left urogomphus, lateral view. *d, e, L. pudicus* Brown: *d,* urogomphi, dorsal view; *e,* left urogomphus, lateral view. *f, g, L. hieroglyphicus* (Say): *f,* urogomphi, dorsal view; *g,* left urogomphus, lateral view.

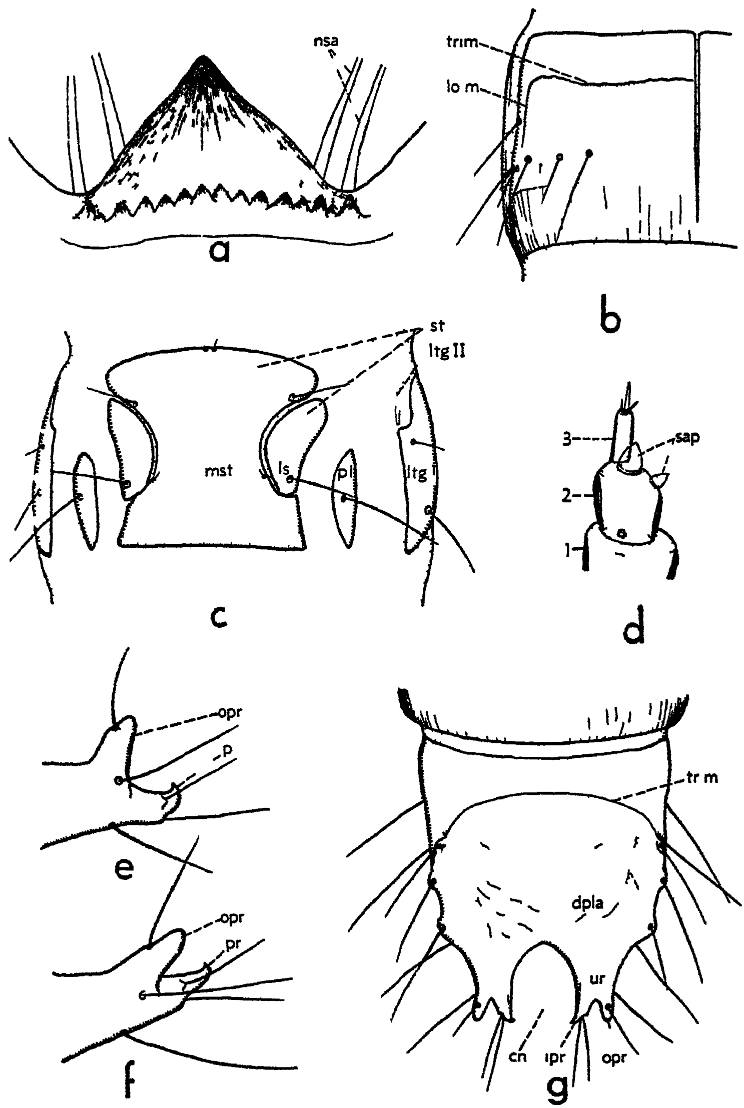

FIG 18.—*Ludius triundulatus* group

a-d, f, g, Ludius triundulatus (Randall) *a* nasale and subnasale, ventral view, *b,* mediotergite of fifth abdominal segment dorsal view *c,* fifth abdominal segment, ventral view, *d* second and third segments of left antenna, ventral view, *f* left urogomphus lateral view, *g,* ninth abdominal segment, dorsal view *e, L nebraskensis* (Bland) (?) left urogomphus, lateral view

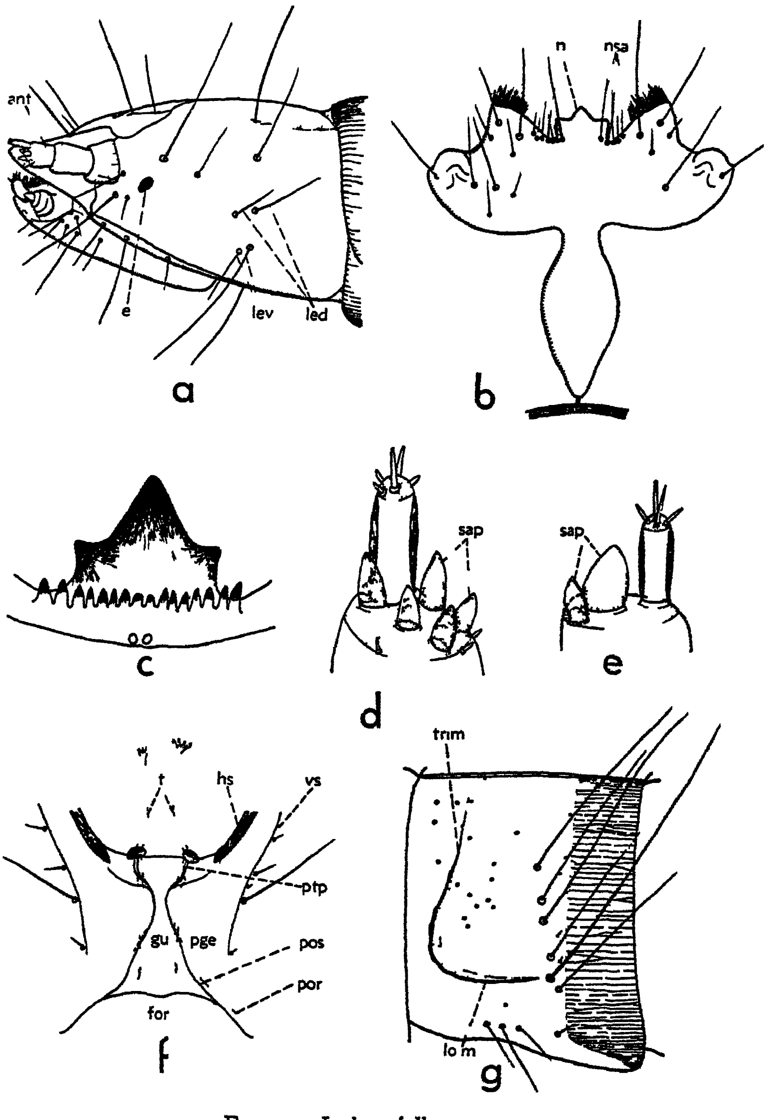

FIG 19—*Ludius fallax* group

a, b, d f, g, Ludius tessellatus (Linnaeus) *a,* head, lateral view, *b,* frontoclypeal region, dorsal view, *d* third segment and tip of second segment of left antenna, medioventral view *f,* gular area, showing position of tentorium, ventral view, *g* mediotergite of fourth abdominal segment, dorsolateral view *c, e, L castaneus* (Linnaeus) *c,* nasale and subnasale, ventral view, *e,* third segment and tip of second segment of left antenna, lateral view

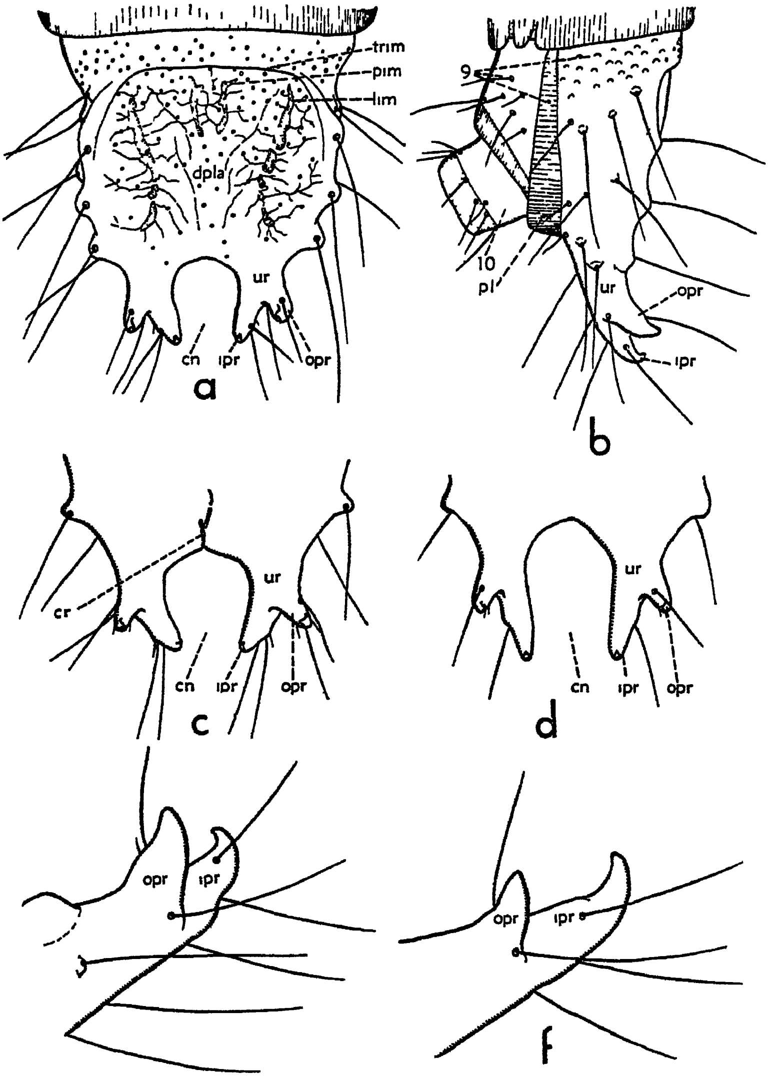

FIG. 20—*Ludius fallax* group.

a, b, e, Ludius tessellatus (Linnaeus): *a,* ninth abdominal segment, dorsal view; *b,* ninth and tenth abdominal segments, lateral view; *e,* left urogomphus, lateral view. *c, L. castaneus* (Linnaeus): urogomphi, dorsal view. *d, f, L. bombycinus* (Germar). *d,* urogomphi, dorsal view (drawn from larval exuvium); *f,* left urogomphus, lateral view (drawn from larval exuvium).

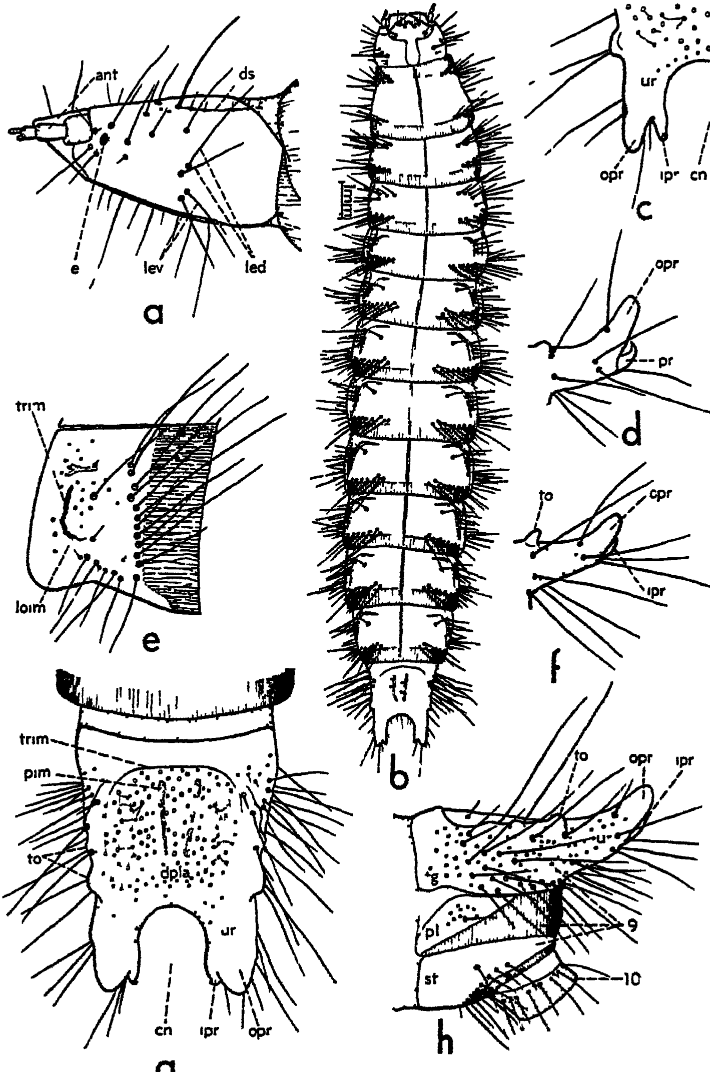

FIG 21.—*Ludius rotundicollis* group.

a, b, e, g, h, Ludius rotundicollis (Say) ("Western species"). *a*, head, lateral view (ventral mouthparts omitted); *b*, whole larva dorsal view; *e*, mediotergite of fourth abdominal segment, dorsolateral view; *g*, ninth abdominal segment, dorsal view; *h*, ninth and tenth abdominal segments, lateral view. *c, d, L. sulcicollis* (Say): *c*, left urogomphus, dorsal view; *d*, left urogomphus, lateral view. *f, L. rotundicollis* (Say) ("Eastern species"): left urogomphus, lateral view.

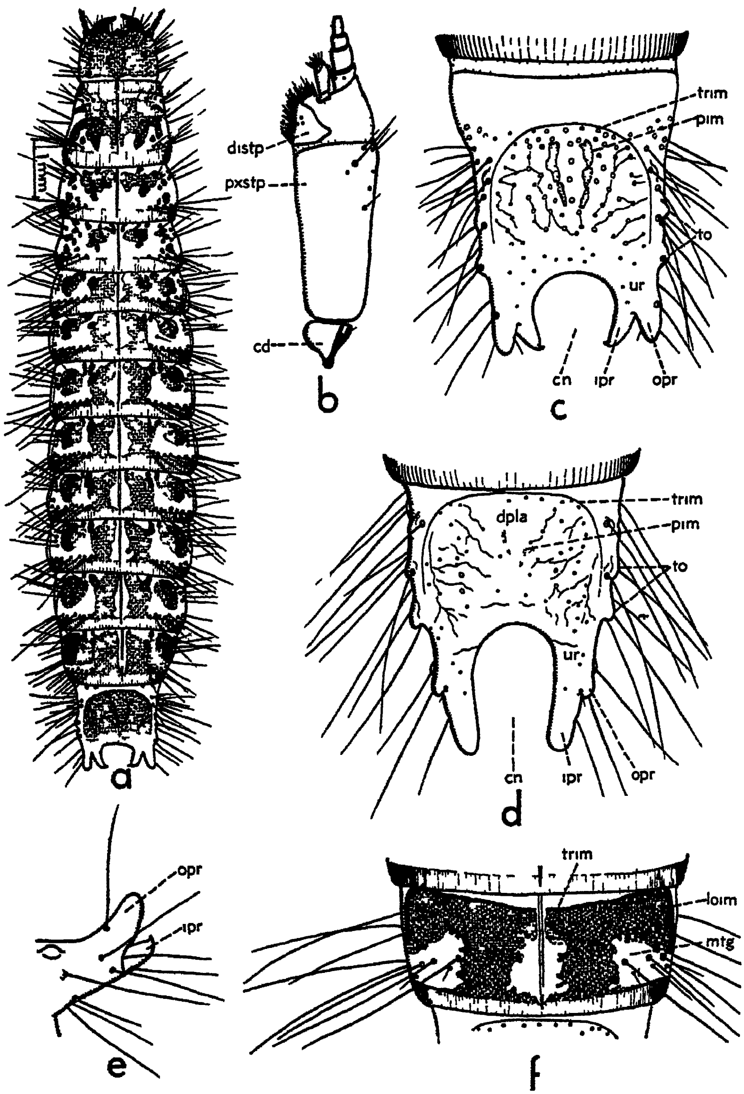

FIG. 22.—Species of *Ludius.*

a-c, e, Ludius cinctus (Paykull): *a,* whole larva, dorsal view (showing color pattern); *b,* left maxilla, ventral view; *c,* ninth abdominal segment, dorsal view (color pattern omitted); *e,* left urogomphus, lateral view. *d, f, L. bipustulatus* (Linnaeus): *d,* ninth abdominal segment, dorsal view (color pattern omitted); *f,* eighth abdominal segment, dorsal view (showing color pattern).

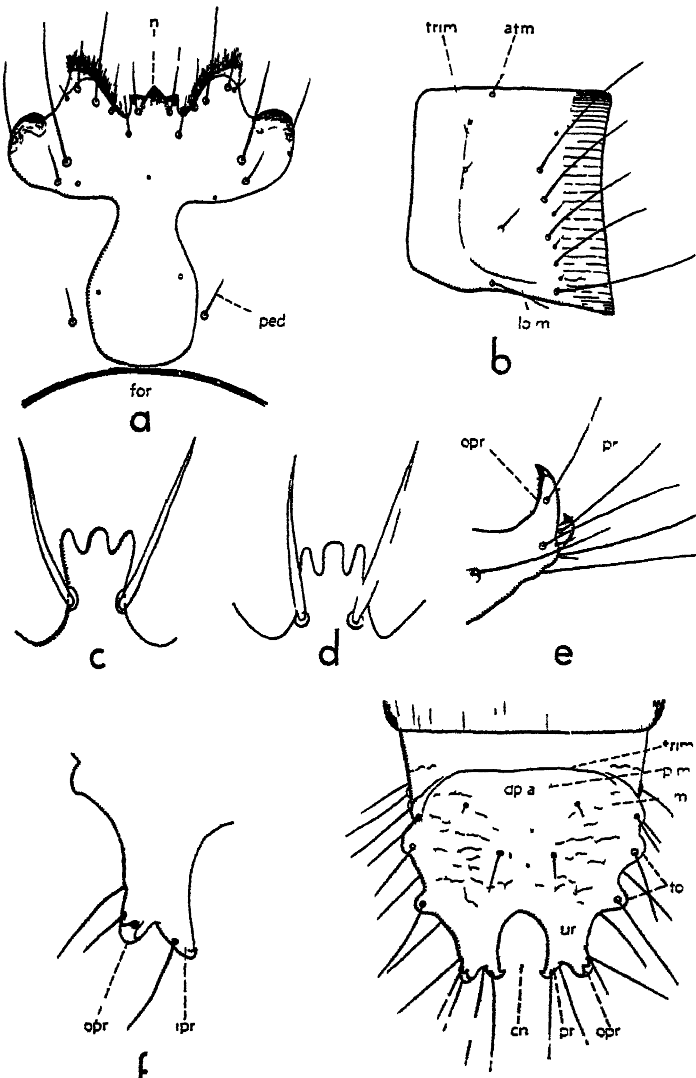

FIG. 23.—*Ludius nitidulus* group.

a, b, e, g, Ludius nitidulus (LeConte): *a*, frontoclypeal area, dorsal view; *b*, left mediotergite of seventh abdominal segment, dorsolateral view; *e*, left urogomphus, lateral view; *g*, ninth abdominal segment, dorsal view. *c, L. rufopleuralis* Fall (?): nasale, dorsal view. *d, f, L. nigricornis* (Panzer) (?): *d*, nasale, dorsal view; *f*, left urogomphus, dorsal view.

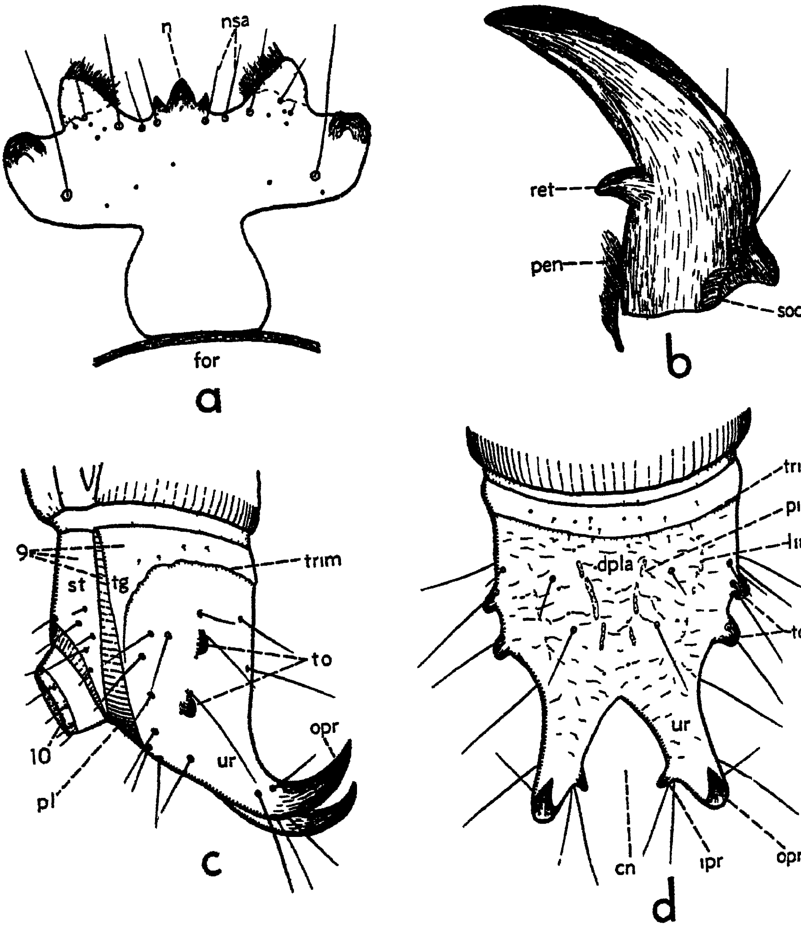

FIG. 24—*Ludius divaricatus* (LeConte).

a, frontoclypeal area, dorsal view; *b*, right mandible, dorsal view; *c*, ninth and tenth abdominal segments, lateral view; *d*, ninth abdominal segment, dorsal view.

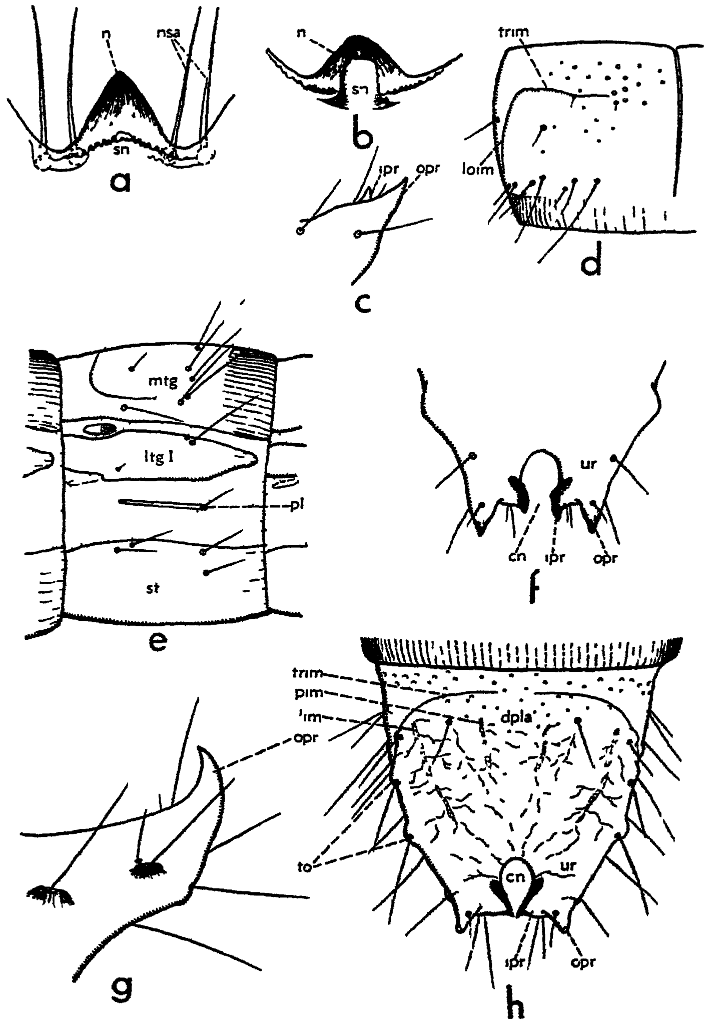

FIG. 25.—Species of *Ludius*.

a, *Ludius cupreus cupreus* (Fabricius): nasale and subnasale, ventral view. *b*, *c*, *f*, *L. appressus* (Randall) (drawn from larval exuvium): *b*, nasale and subnasale, ventral view; *c*, tip of left urogomphus, lateral view; *f*, urogomphi, dorsal view. *d*, *e*, *g*, *h*, *L. cupreus aeruginosus* (Fabricius): *d*, left mediotergite of eighth abdominal segment, laterodorsal view; *e*, fourth abdominal segment, ventrolateral view; *g*, left urogomphus, lateral view; *h*, ninth abdominal segment, dorsal view.

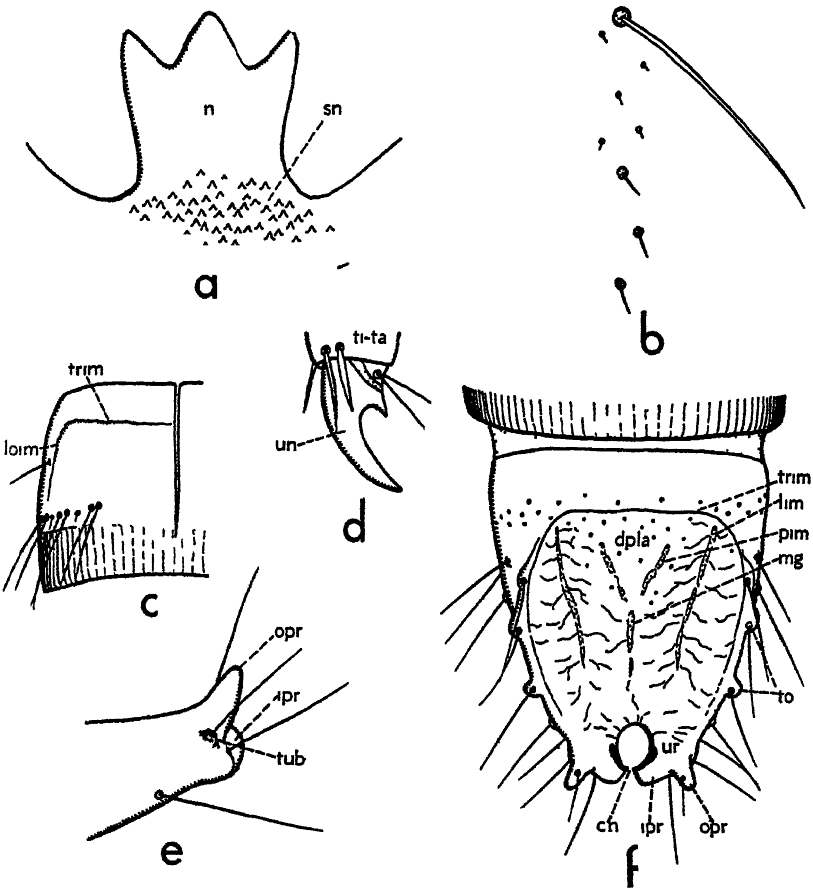

FIG. 26.—*Ludius resplendens aerarius* (Randall).

a, nasale and subnasale, ventral view; *b*, setal arrangement in left dorsal epicranial sulcus; *c*, left mediotergite of third abdominal segment, dorsal view; *d*, ungula of right prothoracic leg, anterior aspect; *e*, left urogomphus, lateral view, *f*, ninth abdominal segment, dorsal view.

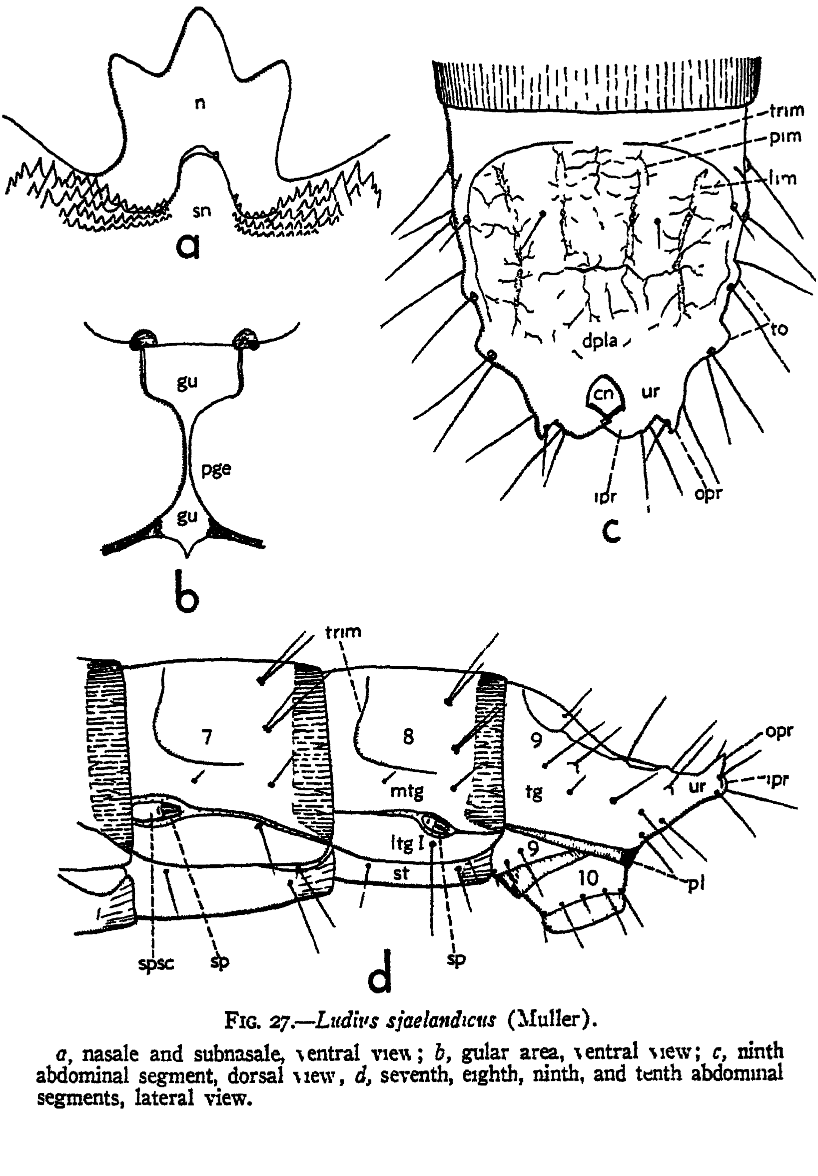

FIG. 27.—*Ludius sjaelandicus* (Muller).

a, nasale and subnasale, ventral view; *b*, gular area, ventral view; *c*, ninth abdominal segment, dorsal view, *d*, seventh, eighth, ninth, and tenth abdominal segments, lateral view.

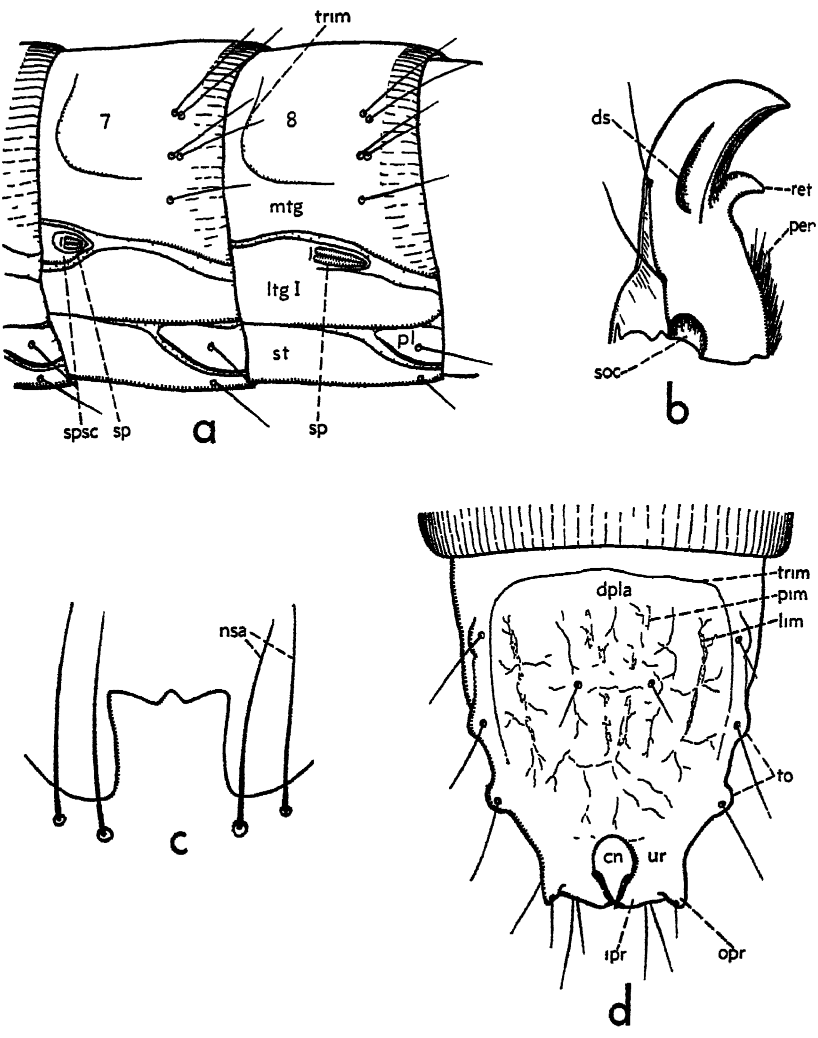

FIG. 28.—*Ludius pyrrhos* (Herbst).

a, seventh and eighth abdominal segments, lateral view; *b*, left mandible, dorsal view; *c*, nasale, dorsal view; *d*, ninth abdominal segment, dorsal view.

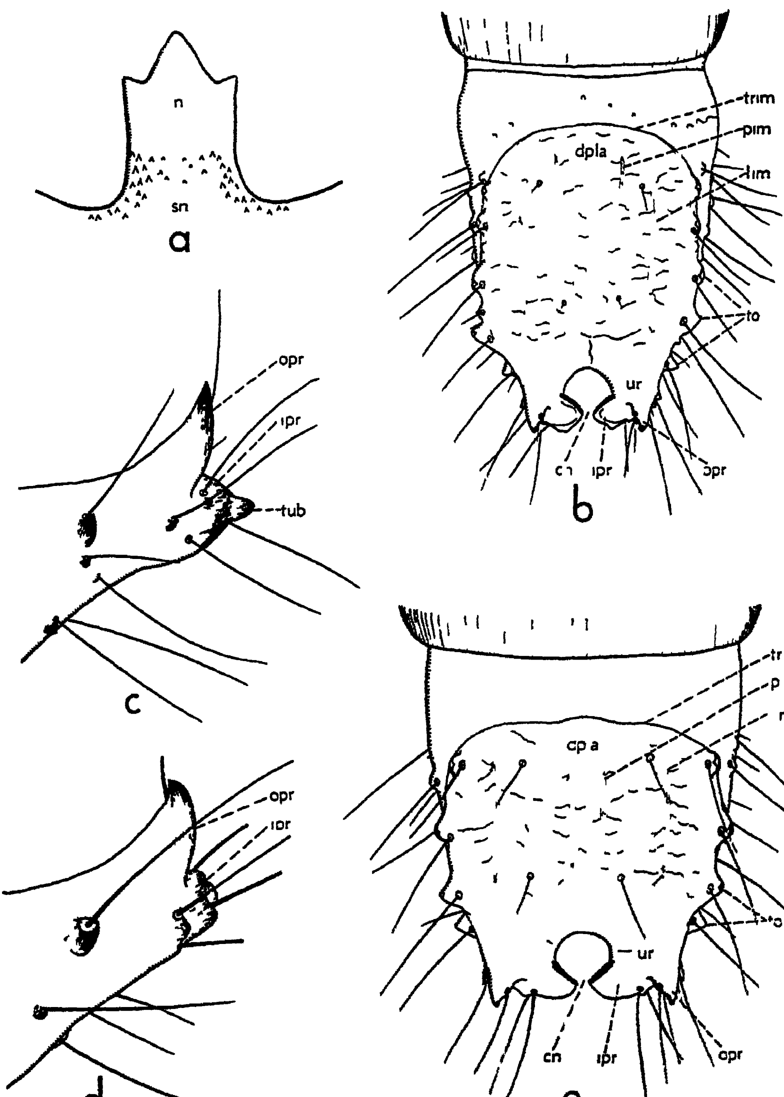

FIG. 29—*Ludius limoniiformis* group.

a-c, *Ludius limoniiformis* (Horn) (?): *a*, nasale and subnasale, ventral view; *b*, ninth abdominal segment, dorsal view; *c*, left urogomphus, lateral view. *d-e*, *L. cylindriformis* (Herbst) (?) *d*, left urogomphus, lateral view; *e*, ninth abdominal segment, dorsal view.

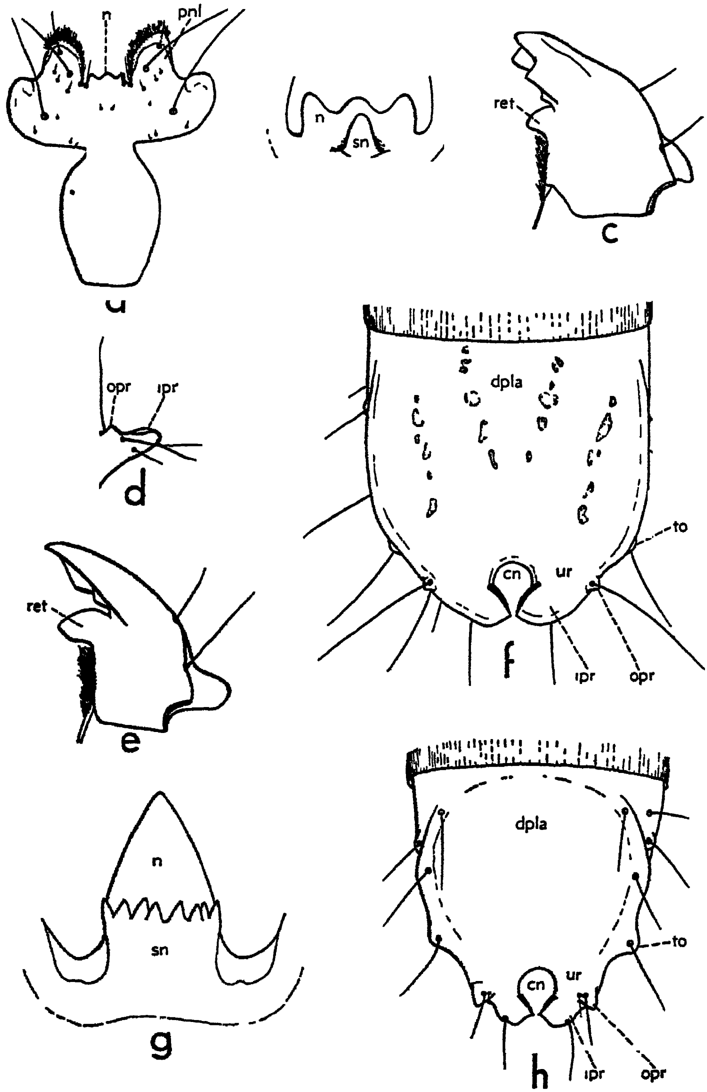

FIG. 30.—Species of *Limonius.*

a-d, f, Limonius aeneoniger (DeGeer) (=*Pheletes bructeri* Panzer): *a,* frontoclypeal area, dorsal view; *b,* nasale and subnasale, ventral view; *c,* right mandible, dorsal view (probably somewhat eroded); *d,* left urogomphus, lateral view; *f,* ninth abdominal segment, dorsal view. *e, g, h, L. pilosus* (Leske) (?): *e,* right mandible, dorsal view; *g,* nasale and subnasale, ventral view; *h,* ninth abdominal segment, dorsal view.

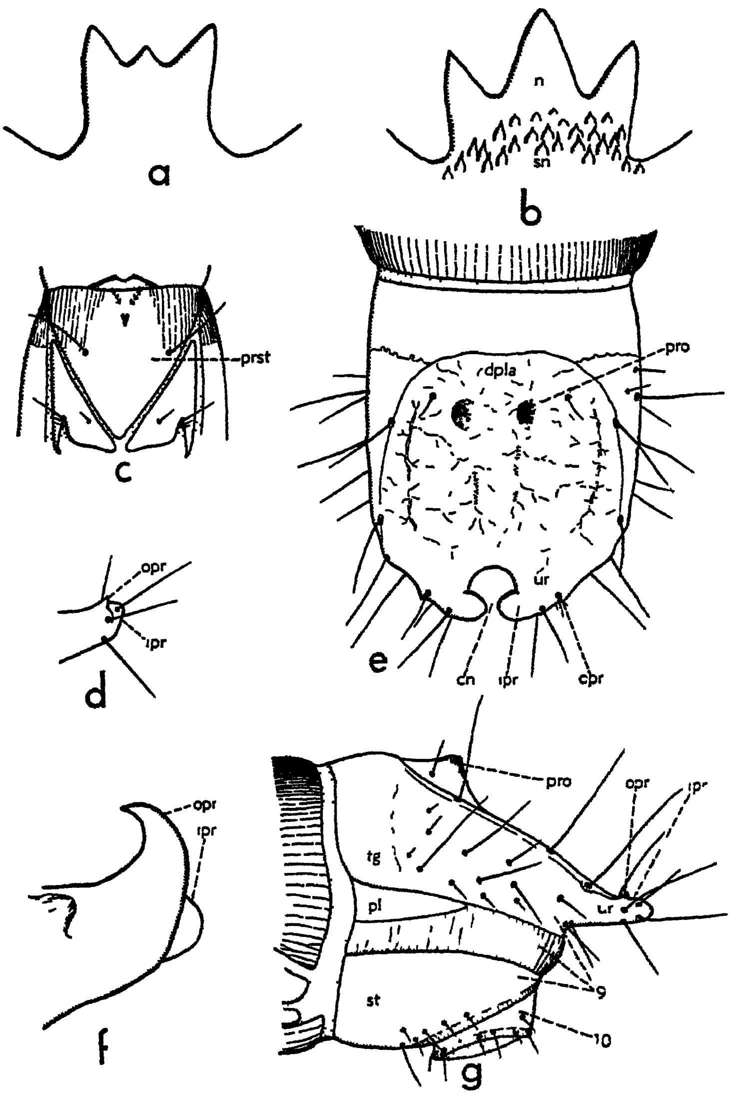

FIG. 31.—Species of *Limonius*.

a, e, g, Limonius pectoralis LeConte: *a*, nasale, dorsal view; *e*, ninth abdominal segment, dorsal view; *g*, ninth and tenth abdominal segments, lateral view. *b, c, L. dubitans* LeConte (=*Nothodes dubitans*): *b*, nasale and subnasale, ventral view; *c*, presternal area of prothorax, ventral view. *d, L. aeger* LeConte: left urogomphus, lateral view. *f, L. subauratus* LeConte (?): left urogomphus, lateral view.

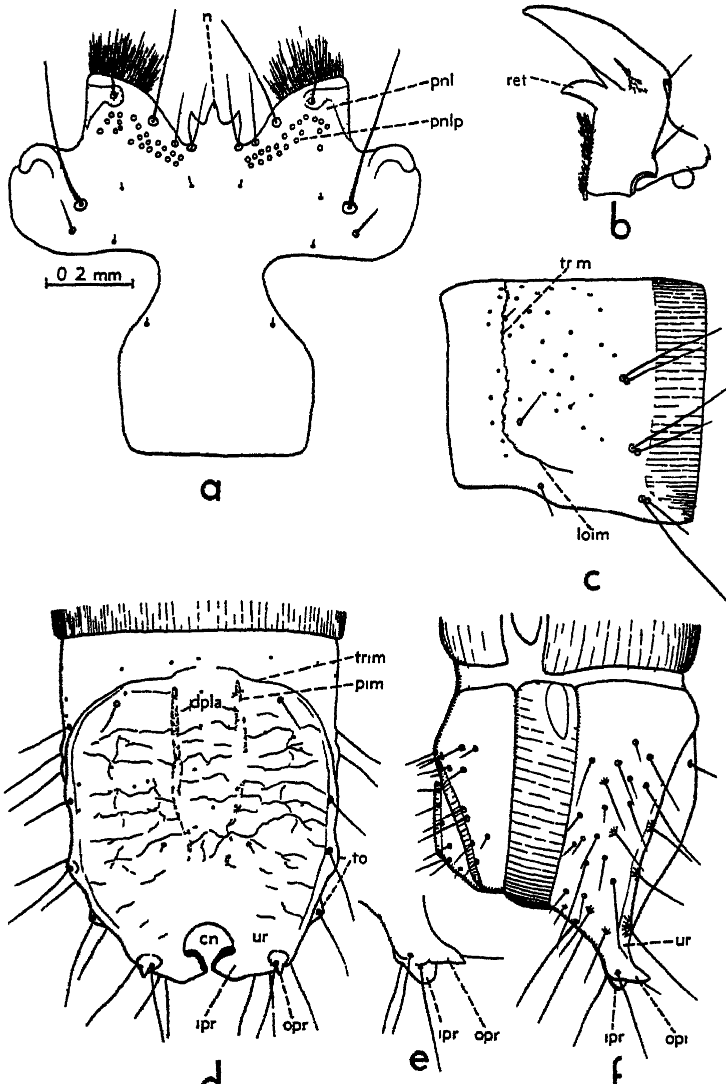

FIG. 32.—*Limonius canus* group.

a-e, Limonius dubitans LeConte (=*Nothodes dubitans*): *a*, frontoclypeal area, dorsal view, *b*, right mandible, dorsal view; *c*, left mediotergite of fourth abdominal segment, lateral view; *d*, ninth abdominal segment, dorsal view; *e*, left urogomphus, lateral view. *f, L. ectypus* (Say) (?): ninth and tenth abdominal segments, lateral view.

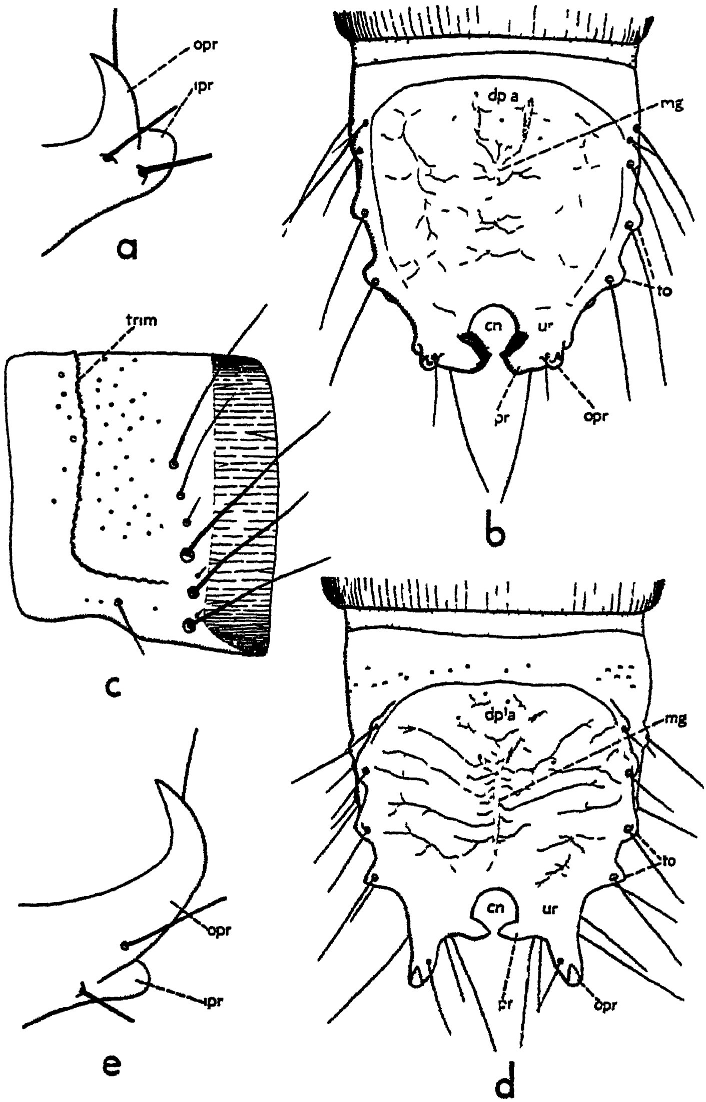

FIG 33—*Elathous bicolor* and *Lepturoides linearis.*

a, b, Elathous bicolor (LeConte): *a*, left urogomphus, lateral view; *b*, ninth abdominal segment, dorsal view *c-e, Lepturoides linearis* (Linnaeus): *c*, left mediotergite of fourth abdominal segment, dorsolateral view; *d*, ninth abdominal segment, dorsal view; *e*, left urogomphus, lateral view.

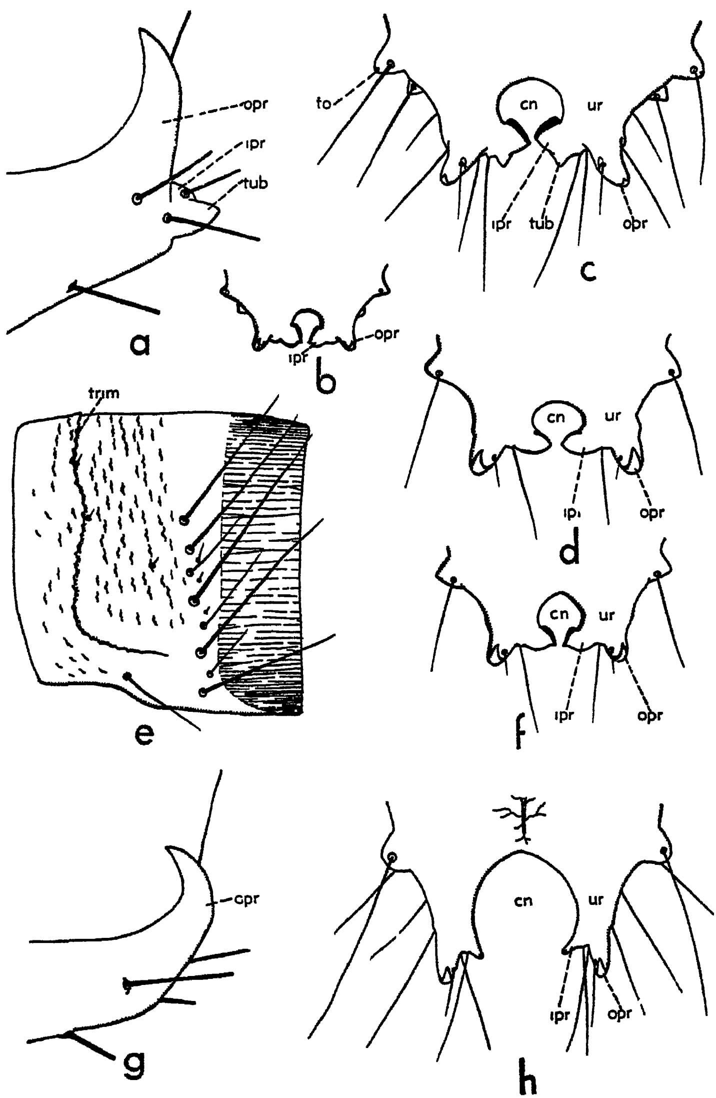

FIG. 34.—Species of *Athous*.

a, c, Athous haemorrhoidalis (Fabricius): *a*, left urogomphus, lateral view; *c*, urogomphi, dorsal view. *b, A. vittatus* (Fabricius): urogomphi, dorsal view. *d, e, A. rufifrons* (Randall): *d*, urogomphi, dorsal view; *e*, left mediotergite of fourth abdominal segment, dorsolateral view. *f, A. brightwelli* (Kirby): urogomphi, dorsal view. *g, h, A. mutilatus* Rosenhauer: *g*, left urogomphus, lateral view; *h*, urogomphi, dorsal view.

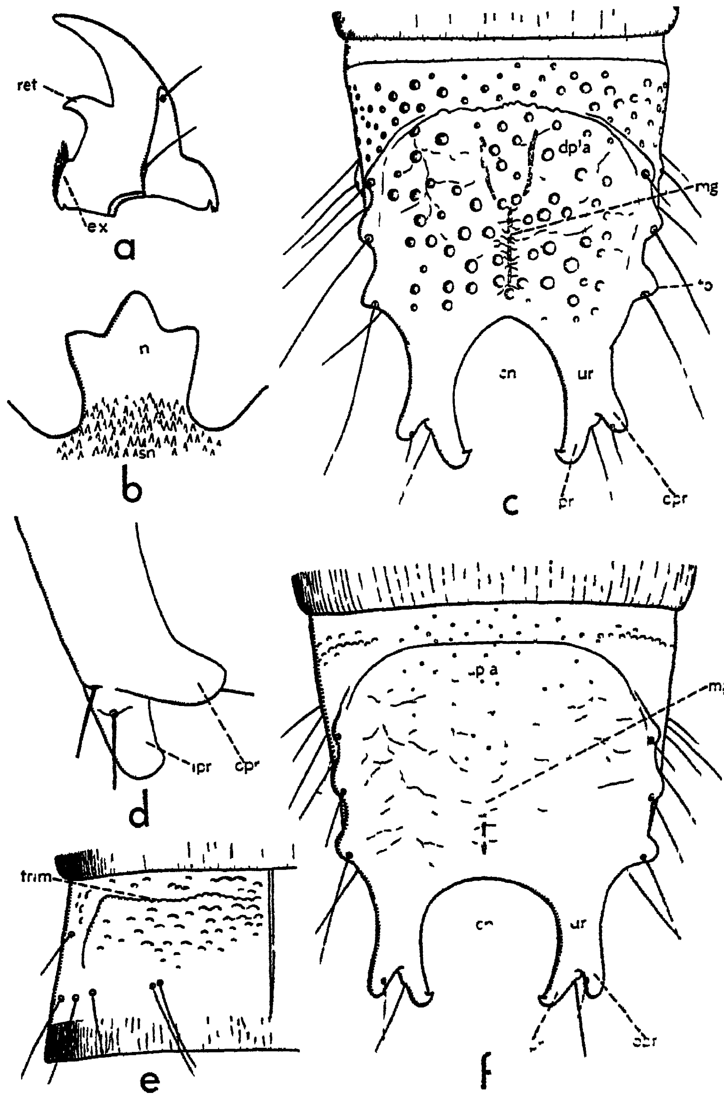

FIG. 35.—*Athous cucullatus* group.

a, c, d, Athous cucullatus (Say): *a,* right mandible, dorsal view, *c,* ninth abdominal segment, dorsal view; *d,* left urogomphus, lateral view. *b, e, f, A. scapularis* (Say): *b,* nasale and subnasale, ventral view; *e,* left mediotergite of fourth abdominal segment, laterodorsal view; *f,* ninth abdominal segment, dorsal view.

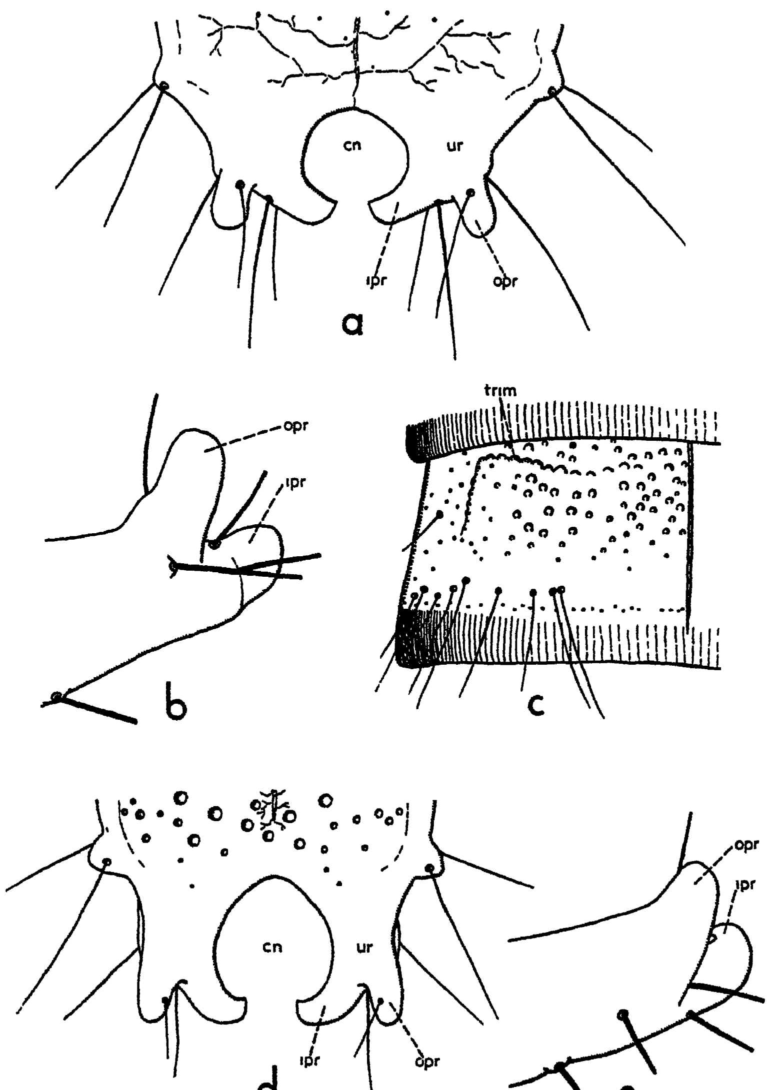

FIG. 36.—*Athous undulatus* group.

a-c, *Athous* (*Harminius*) *undulatus* (DeGeer): *a*, urogomphi, dorsal view; *b*, left urogomphus, lateral view; *c*, left mediotergite of fifth abdominal segment, laterodorsal view. *d*, *e*, *A. villosus* (Geoffroy): *d*, urogomphi, dorsal view; *e*, left urogomphus, lateral view.

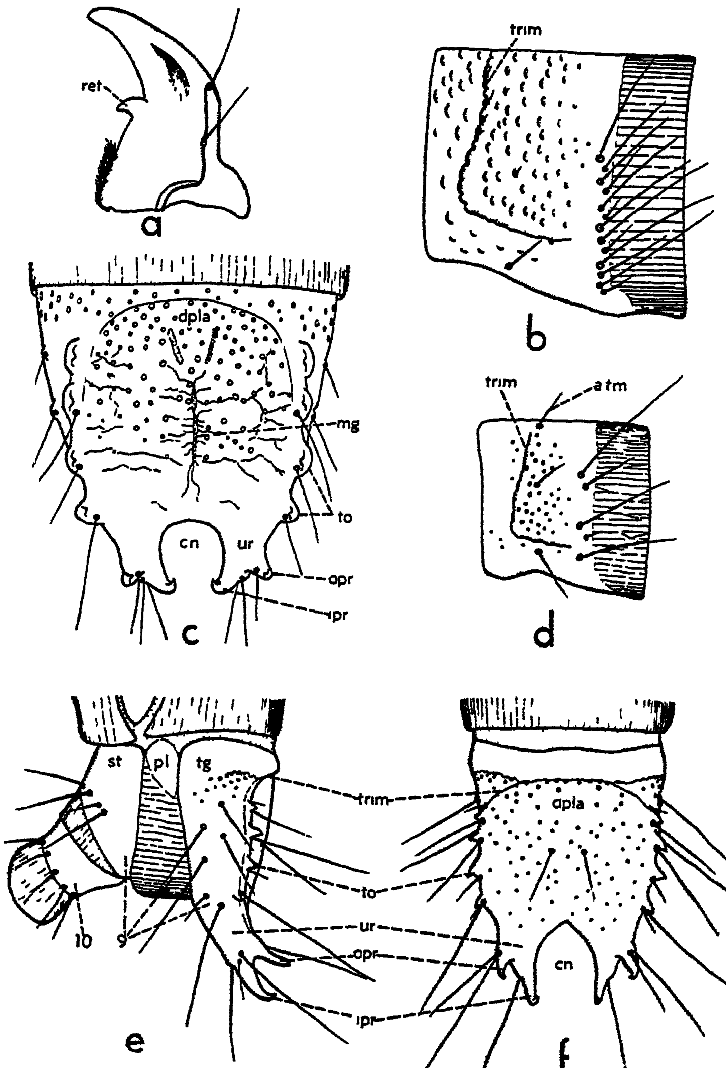

FIG. 37.—Species of *Hemicrepidius* and *Crepidomenus*.

a, Hemicrepidius sp., near *carbonatus* (LeConte): right mandible, dorsal view (drawn from larval exuvium of a reared specimen). *b, Hemicrepidius* sp. (unidentified): left mediotergite of fourth abdominal segment, dorsolateral view. *c, H. memnonius* (Herbst): ninth abdominal segment, dorsal view (drawn from larval exuvium of a reared specimen). *d-f, Crepidomenus queenslandicus* Blair: *d*, left mediotergite of third abdominal segment, dorsolateral view; *e*, ninth and tenth abdominal segments, lateral view; *f*, ninth abdominal segment, dorsal view.

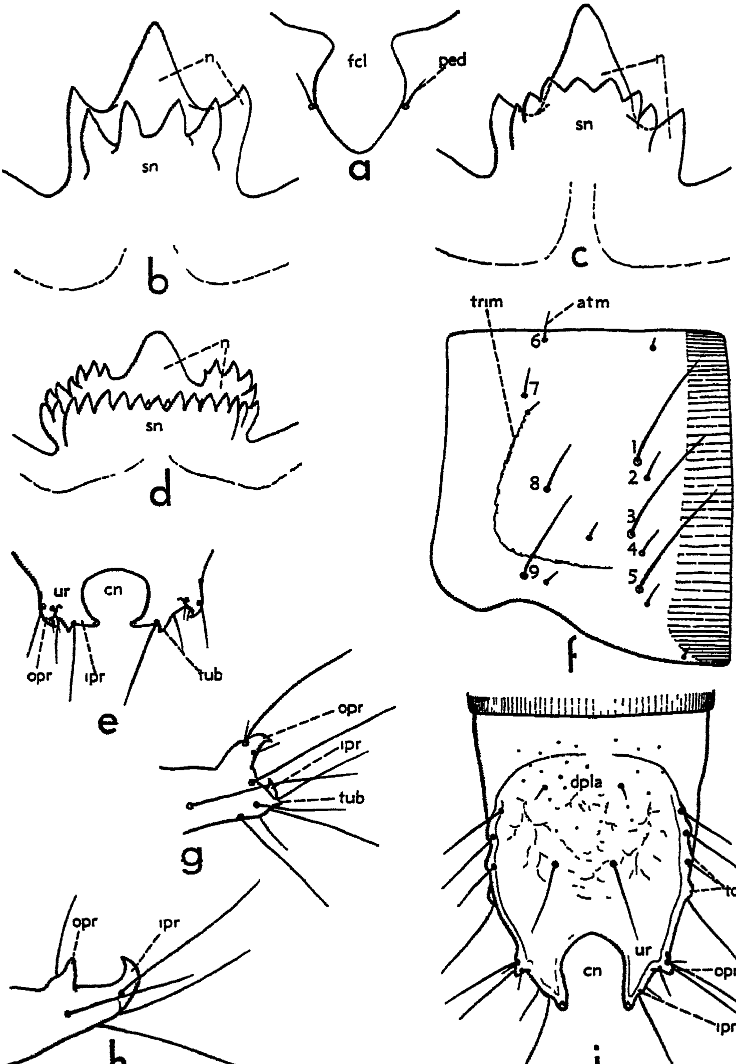

FIG. 38.—Species of *Cryptohypnus*.

a, c, e, g, Cryptohypnus abbreviatus (Say): *a*, posterior part of frontoclypeal area showing adjacent setae, dorsal view; *c*, nasale and subnasale, ventral view; *e*, urogomphi, dorsal view; *g*, left urogomphus, lateral view. *b, h, i, C. riparius* (Fabricius): *b*, nasale and subnasale, ventral view; *h*, left urogomphus, lateral view; *i*, ninth abdominal segment, dorsal view. *d, f, C. funebris* Candeze. *d*, nasale and subnasale, ventral view; *f*, left mediotergite of fourth abdominal segment, dorsolateral view (showing complete complement of setae; the numbered setae are found in all known *Cryptohypnus* larvae).

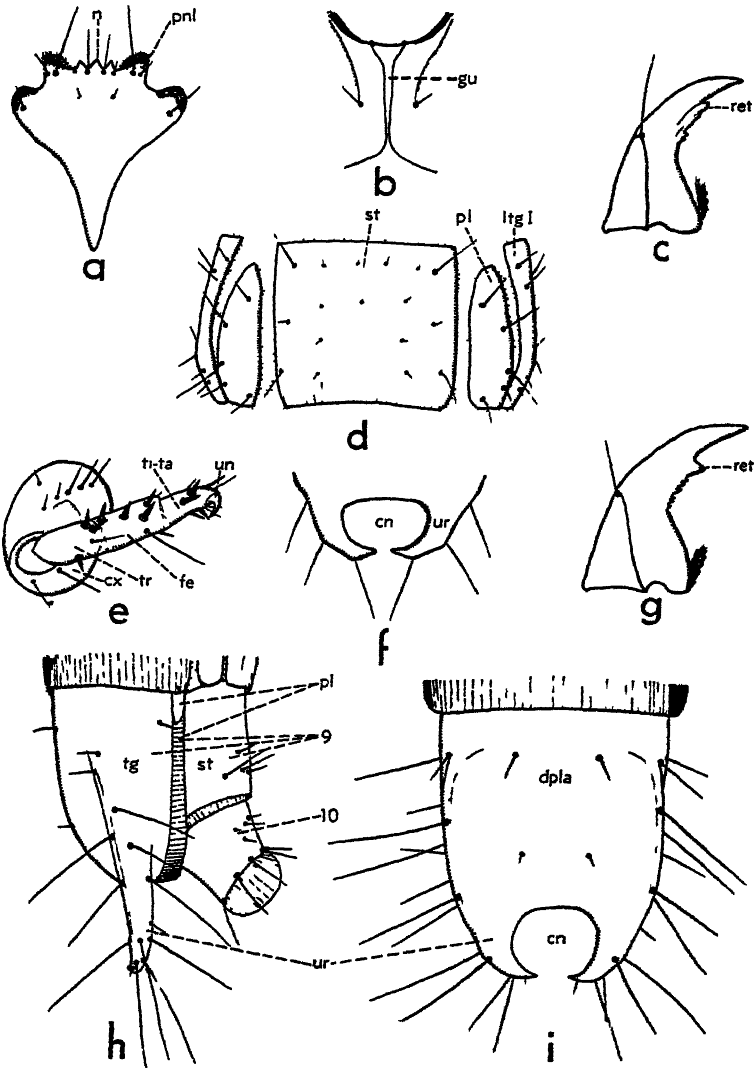

FIG. 39.—*Hypnoidus dubius* and *Hypnoidus musculus.*

a-e, h, i, Hypnoidus dubius (Horn): *a,* frontoclypeal area, dorsal view; *b,* gular area, ventral view; *c,* left mandible, dorsal view; *d,* third abdominal segment, ventral view; *e,* left mesothoracic leg, mediocephalic view; *h,* ninth and tenth abdominal segments, lateral view; *i,* ninth abdominal segment, dorsal view. *f, g, H. musculus* (Eschscholtz): *f,* urogomphi, dorsal view; *g,* left mandible, dorsal view.

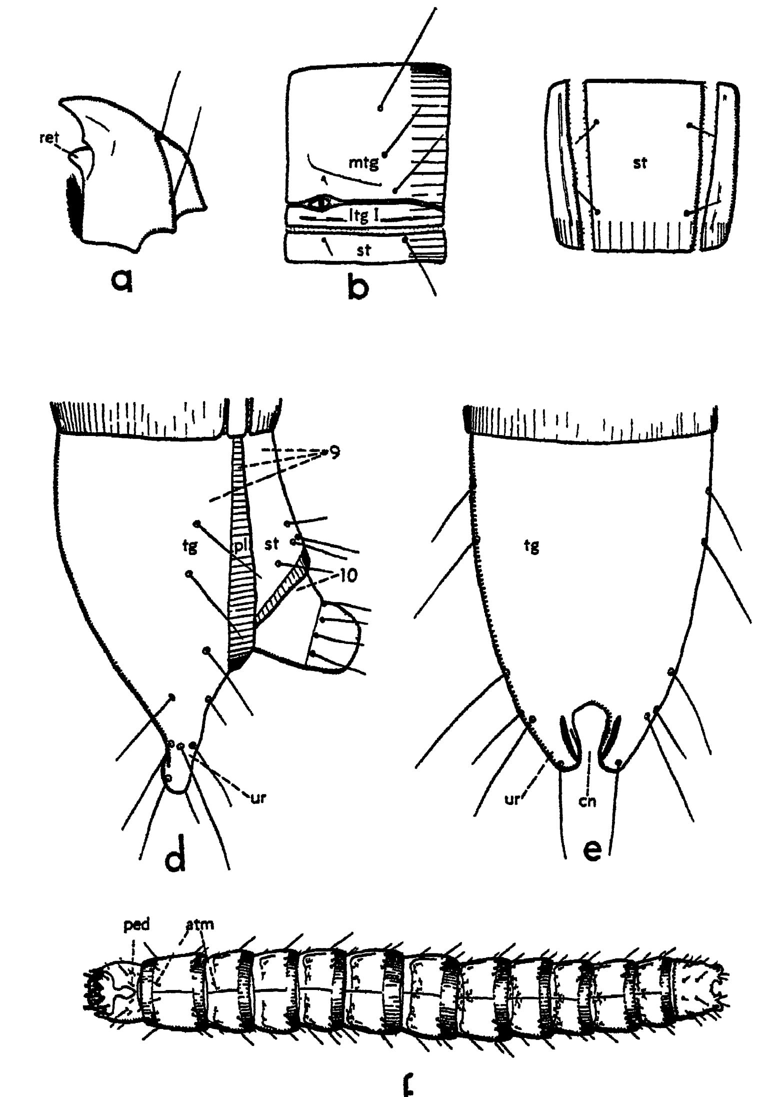

FIG. 40.—*Eanus decoratus* and *Melanactes densus.*

a-e, Eanus decoratus (Mannerheim): *a,* right mandible, dorsal view; *b,* third abdominal segment, lateral view; *c,* third abdominal segment, ventral view; *d,* ninth and tenth abdominal segments, lateral view; *e,* ninth abdominal segment, dorsal view. *f, Melanactes densus* LeConte: larva, dorsal view.

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TREE GROWTH AND RAINFALL—A STUDY OF CORRELATION

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TREE GROWTH AND RAINFALL—A STUDY OF CORRELATION AND METHODS[1]

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The purpose of the present study is to test critically the covariation of tree growth and rainfall—tree growth as measured by the thicknesses of growth layers on increment cores. Three desiderata were the bases of the study. First, an altitudinal zone was to be selected above the region of violent fluctuations of soil moisture but below the region of excessive accumulation and possible carry-over from season to season. This would avoid the forest-border zone where temporary depletion of soil moisture during the growing season could bring growth to a halt temporarily and possibly cause multiplicity of growth layers during that season.

Second, the number of trees sampled was to be held to a minimum in order to avoid excessive duplication of record and to avoid inclusion of trees from habitats so diverse that the merged record would become blurred. The number, however, was to be sufficiently large to absorb any differences in relative growth-layer thicknesses from tree to tree due to slight variations in site factors local to the individual trees.

Third, the trees were to be selected *in the field* on the basis of ecologic principles, after which each core, unless marred by accident or disease, would enter into the group record whether or not the relative thicknesses of its growth layers closely agreed with those of the other cores.

The writer is aware[2] of the shortcomings and the possible misrepresentation inherent in the use of rain-gauge records taken some

[1] Grateful acknowledgment is made to Dr. A. Wetmore and to the Smithsonian Institution, which supported the entire project. To Dr. R. Sidwell gratitude is due for courtesies extended in the field. Herbert Gross, of Macalester College, was of much assistance not only in the preparation of the figures but also in the lively interest he evinced in the problem. Rainfall data from 1931 to 1946 were obligingly supplied by the Weather Bureau office in Albuquerque, N. Mex.

[2] Bot. Rev., vol. 7, pp. 649-713, 1941; Journ. Forestry, vol. 40, pp. 614-620, 1942.

miles from the site of the trees, in the use of a single radius to represent the entire volume growth of a tree, and in the emphasis on a single growth factor. However, if significant results can be obtained, in spite of handicaps, by proper selection of trees from the correct habitat, a critical test is highly worth while in view of the simplicity and directness of method. Heretofore, many of the correlations[3] between tree growth and rainfall have been discouraging unless the data were smoothed to an extent that direct responses were masked and only general trends revealed.

LOCATION AND TREE DESCRIPTION

The increment cores came from trees that grew near and on Holman Pass, in the Sangre de Cristo Range of north-central New Mexico, about 41 miles by road or about 35.5 miles airline north-northwest from Las Vegas (fig. 1). In so far as the life zones were concerned, the collection extended upward from mid-Transition into the lower portion of the Canadian.

All the trees sampled were dominant or codominant and in the timber stage of development.[4] On the whole, the ponderosa pines were slightly more mature than the other species. Neighboring trees not sampled were sufficiently distant to avoid undue competitive influence as far as site factors were concerned. Furthermore, the locations were chosen so that abnormal drainage toward or away from the trees was at a minimum. The soils were in no sense tight or lacking in aeration.

In all, nine trees were sampled and designated by the initials HPC, for Holman Pass Collection. The trees from which samples HPC 1 to 4 were taken grew on a nearly flat area a mile southeast of the Pass at an elevation of 9,000 feet. All four were within 150 yards of one another. The black soil contained numerous pebbles and boulders. Cores HPC 5 and 6 came from trees that grew on the Pass itself at an elevation of 9,450 feet. In spite of the fact that the site was on top of the actual pass, the trees stood in the middle of a broad, essentially flat area. The soil was derived from shale and sandstone bedrock, fragments of which remained. Between 7 and 8 miles west of the Pass and down Rio Pueblo Canyon the location of

[3] Many of these are listed and discussed in Bot. Rev., vol. 7, pp. 687-698, 705-713, 1941.

[4] Following the classification of James W. Toumey and Clarence F. Korstian, Foundations of silviculture upon an ecological basis, p. 268, 1937. New York.

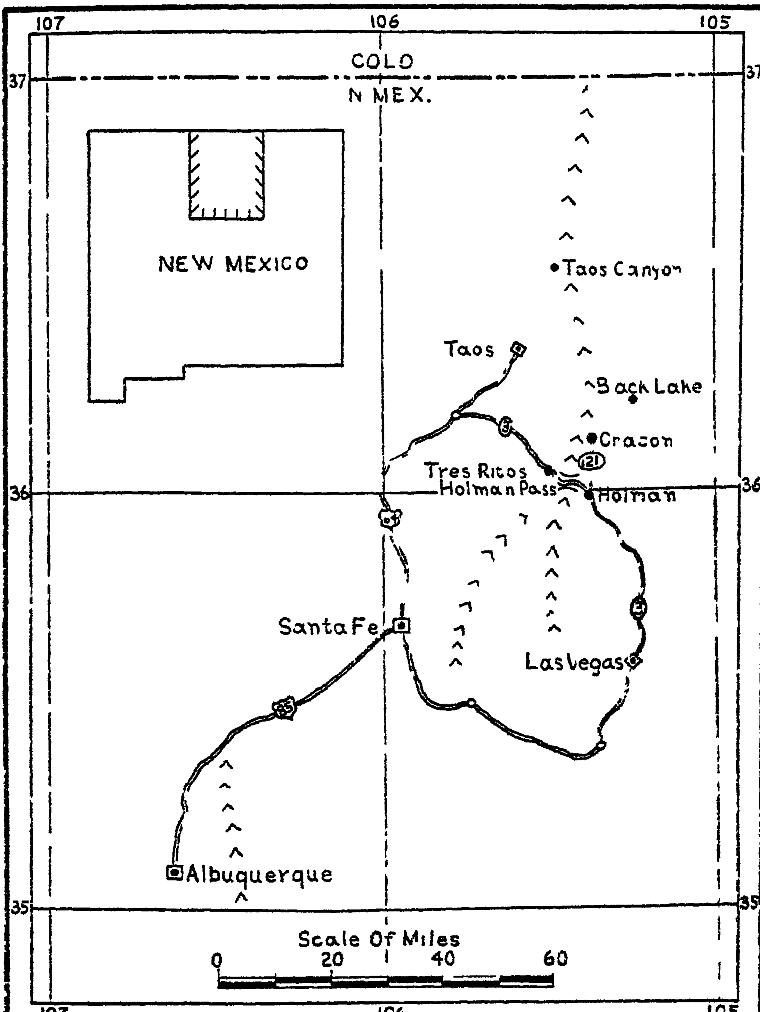

FIG. 1.—General location map for Holman Pass collection and rainfall stations.

the trees for HPC 7 to 9 was chosen at an elevation of approximately 8,000 feet. Here ponderosa pines were more mature and more dominant than at the other two sites. The trees grew on top of a very gently sloping terrace whose edge stood 20 feet above the stream channel. Toward the south the terrace top rose gently to a steeper, heavily wooded slope over 400 feet away. The soil, granitic in composition, contained numerous pebbles and boulders.

Individual tree and core descriptions are given below in concise form:

HPC 1. Ponderosa pine (*Pinus ponderosa*). 14 inches DBH. Average thickness of growth layers 1.61 mm. Range 1850-1946. Growth-layer sequence variable. Average departure from mean 0.58 mm., or 36 percent.

HPC 2. Ponderosa pine. 12 inches DBH. Distant 100 yards from HPC 1. Average thickness of growth layers 1.86 mm. Range 1850-1946. Growth-layer sequence variable. Average departure from the mean 0.54 mm., or 29 percent.

HPC 3. Foxtail pine (*P. aristata*). 24 inches DBH. Midway between HPC 1 and 2. Average width of growth layers 1.32 mm. Range 1770-1946. Growth-layer sequence variable. Average departure from mean 0.51 mm., or 39 percent.

HPC 4. White fir (*Abies concolor*). 15 inches DBH. Wettest location for group east of Pass; slight drainage toward tree. Average thickness of growth layers 2.93 mm., corrected to average 1.46 mm. Range 1880-1946. Growth-layer sequence only fairly variable. Average departure from mean 0.57 mm., or 39 percent.

HPC 5. Douglas fir (*Pseudotsuga taxifolia*). 15 inches DBH. Average width of growth layers 1.16 mm. Range 1810-1946. Growth-layer sequence variable. Average departure from mean 0.45 mm, or 39 percent.

HPC 6. Foxtail pine. 14 inches DBH. Distant 20 yards from HPC 5. Average width of growth layers 1.38 mm. Range 1820-1946. Growth-layer sequence uniform. Average departure from mean 0.36 mm., or 26 percent.

HPC 7. Ponderosa pine. 23 inches DBH. Distant 70 feet from edge of terrace above stream. Average thickness of growth layers 1.91 mm. Range 1830-1946. Growth-layer sequence uniform and rhythmic. Average departure from mean 0.52 mm., or 27 percent.

HPC 8. Ponderosa pine. 13 inches DBH. Distant 20 feet from edge of terrace above stream. Least mature. Ground-water relations make site better drained than that of HPC 7. Average thickness of growth layers 3.74 mm.; corrected to average 1.46 mm. Range 1897-1946. Growth-layer sequence only fairly variable. Average departure from mean 0.53 mm., or 36 percent.

HPC 9. Ponderosa pine. 19 inches DBH. Midway between terrace edge and base of steep slope. Wettest location for trees west of Pass. Average thickness of growth layers 2.71 mm.; corrected to average 1.46 mm. Range 1857-1946. Growth-layer sequence variable. Average departure from mean 0.44 mm., or 30 percent.

The designations variable, fairly variable, or uniform were assigned directly from the wood by visual judgment alone.

METHODS

Because all cores consisted of sound wood, none was discarded. Furthermore, because site factors such as light, drainage, slope, ground-water relations, and competition were evaluated on the spot as closely as possible, no reason existed immediately after the collection had been made for the rejection of any specimen. The collection was considered a normal representation of the site factors at the three chosen localities even though the sequences differed to a great extent in variability and average growth-layer thicknesses. At the time the cores were taken there seemed to be no reason why different species should show differences except those due to slight variations of site factors peculiar to each tree. Such a factor as soil aeration had to be judged by soil texture and composition and visible soil-water relations. There was no opportunity for analyses or measurements. Indeed, this problem of selection in the field, without measurements, was of great importance: could local site factors be judged with sufficient accuracy to demand the inclusion of each core as a representative specimen in the general collection? If so, choice in the field, based on ecologic principles, would be a dependable method of selection whose integrity could be questioned only on field evidence or its derivatives.

Treatment of the wood.—The cores and the growth layers they contained were subjected to the following procedure to prepare them for correlation among themselves and with rainfall.

1. The cores were glued in a groove sunk into the curved side of half-inch half-round and "shaved" by razor sufficiently to expose the growth layers clearly.[5]

2. Beginning with the increment for 1946, which was complete because of the time of sampling, October 5, 1946, the growth layers were counted inward and dated on the assumption that each sharply bounded layer represented a year.

3. Skeleton [6] plots were set up on coordinate paper, each ordinate representing a year. If a sharply bounded growth layer was decidedly thinner than its immediate neighbors an ink line was drawn on the ordinate appropriate to its date, the height of the line being inversely proportional to the thickness of the growth layer. The resultant skeleton plots and the master plot derived from them are shown on

[5] Principles and methods of tree-ring analysis. Carnegie Institution of Washington Publ. No. 486, p. 6, 1937.

[6] Ibid., pp. 14-16.

figure 2. Thus, the wood specimens were cross-dated with one another; that is, growth layers taken to be equivalent in time were set in line with one another.

4. The thicknesses of the growth layers were measured to hundredths of a millimeter by means of a measuring microscope. These measurements are called raw data in millimeters.

5. The average thicknesses of the growth layers on the sequences HPC 4, 8, and 9 were corrected downward to approximate the averages of the other sequences. Otherwise, if a sequence of high average thickness were one of several merged into a group, its high average would unduly influence the values in the group.

6. The raw data in millimeters of each sequence were changed into percentages of the sequence mean in order to establish an identity of units and an identity of base line between tree growth and rainfall.

7. The raw percentages were smoothed by the formula

$$\frac{a+2b+c}{4}.$$

8. Various sequences were merged into groups and smoothed.

Groups.—The nine sequences divided themselves geographically into three groups—east of the Pass, on the Pass, and west of the Pass. Nevertheless, other groupings were arranged in order to make the tests not only as critical but also as thorough as possible so far as comparison with rainfall was concerned.

The following groups were set up:

Group 1 (G 1). Trees 1-5, 8, and 9. Variable and fairly variable sequences only.

Group 2 (G 2). Trees 1-3, 5, and 9. Variable sequences only.

Group 3 (G 3). Trees 1-3, and 9. Most variable sequences based upon a visual study of the wood samples. Douglas fir omitted.

Group 4 (G 4). Trees 1-4. East of the Pass.

Group 5 (G 5). Trees 5 and 6. On the Pass.

Group 6 (G 6). Trees 8 and 9. West of the Pass, exclusive of the tree whose sequence is uniform.

Group 7 (G 7). Trees 1-9. All trees.

Group 8 (G 8). Trees 1, 2, and 9. Ponderosa pines with variable sequences.

Group 9 (G 9). Trees 7-9. West of Pass.

Group 10 (G 10). Trees 1-3, and 7. From the drier sites.

Group 11 (G 11). Trees 4-6, and 9. From the wetter sites.

The primary groups are numbers 4, 5, 9, 10, 11, and 7.

Selection of rainfall stations and the treatment of data.—A mountainous country permits little choice in the selection of rainfall stations. Fortunately, one station, Chacon, lies approximately 7 miles, airline

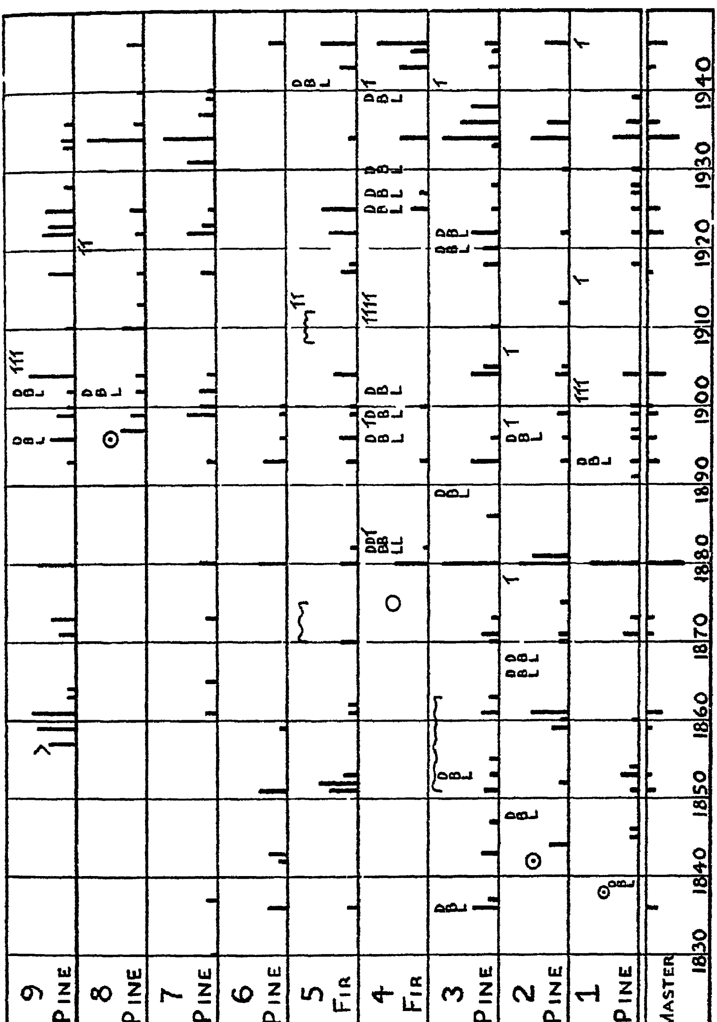

FIG. 2.—Skeleton plots of the nine trees, HPC 1 to 9, and their synthesis into a master plot. The longer the inked line is, the narrower the growth layer. "DBL" means double and "T" means thick. A wavy line includes a group of narrow growth layers. A dot inside of a circle rests on the central growth layer of the tree.

distance, north-northeast of Holman Pass. Unfortunately, its record is short compared with that of Santa Fe, distant 40 miles to the southwest from the Pass. Figure 1 shows the general relations.

Pertinent data in regard to the stations follow:

Chacon: 7 miles north-northeast, east of divide, in the mountains. Elevation 8,510 feet. Length of continuous record 1909-1941.

Black Lake: 19 miles north-northeast, east of the divide, in the mountains. Elevation 8,348 feet. Length of continuous record 1909-1946.

Taos: 24 miles north-northwest, west of mountains. Elevation 6,983 feet. Length of continuous record 1901-1945.

Taos Canyon: 32 miles north, west of divide, in the mountains. Elevation 8,959 feet. Length of continuous record 1909-1941.

Las Vegas: 35.5 miles southeast by south, east of mountains. Elevation 6,400 feet. Length of continuous record 1887-1943.

Santa Fe: 40 miles southwest, west of mountains. Elevation 7,013 feet. Length of continuous record 1850-1944.

Albuquerque: 101 miles southwest, west of Sandia Mountains. Elevation 5,196 feet. Length of continuous record 1892-1946; partial record 1850-1861, 1863-1867, 1878-1879, and 1889-1890.

Month-intervals chosen for the correlative tests between rainfall and tree growth were:

November-May	May-July
January-May	May-August
January-August	April
March-April	May
March-June	June
March-July	July
May-June	August

Rainfall data were then subjected to the treatment here outlined:

1. Addition of monthly rainfall totals in order to obtain the rainfall of the intervals listed above. These sums gave raw data in inches.

2. The raw data of each interval in inches were changed into percentages of its own mean in order to establish an identity of units and an identity of base line between rainfall and tree growth.

3. The raw percentages were smoothed by the formula

$$\frac{a+2b+c}{4}.$$

4. The raw percentages for the stations Chacon, Black Lake, Las Vegas, and Taos Canyon were merged into a group record for the intervals January-August and March-July. These stations were chosen because their interval averages were nearly the same.

Method of correlation.—Because the purpose of the study was the correlation of rainfall variation with growth variations and because

the basic data constitute a continuous time series, the trend method[7] of correlation has been used. This method, in the coefficient *t*, gives a measure of parallel variation combined with amount of that variation. If *t* equals 1.00, the trends in both sets of data, tree growth and rainfall, are wholly parallel or in the same direction; if *t* equals −1.00, the trends are wholly opposite. Tests were constantly made to detect the undue influence of one or two entries should such be present. The ratios of opposite to parallel trends are included in the tables with the trend coefficients. With the trend method of correlation, secular trends or long-period fluctuations did not have to be eliminated. These are ignored for the present especially because the history of the stand and the histories of the individual trees are unknown except as revealed on the wood itself.

The quality of the correlations between tree growth and rainfall on identical years was tested by application of a one-year lag and by reversal of data. In all cases, the correlations dropped to a value of no significance.

Although the purpose of the work was the comparison of year-to-year variations, correlations involving smoothed data (second intermediate) were nevertheless carried through the main part of the calculations. The majority of the coefficients did not increase significantly over those using raw data; in fact, many decreased.

The initial questions, then, to be answered by use of the trend method, were: If rainfall increases or decreases, does tree growth, as shown by such simply obtained samples as increment cores, increase or decrease in like direction? To which rainfall interval does the tree growth correspond? As the work progressed new problems came to light and soon carried the study far beyond the original objectives.

STUDY OF THE GROWTH LAYERS

Cross-dating.—This process consists of establishing the identity in time of growth layers on different sequences by matching narrow growth layers, in particular, from one specimen to another. Judgment as to narrowness depends upon visual comparison with immediately adjacent growth layers and should not be confused with or substituted for mathematical expressions. Obviously, cross-dating can possess various degrees of excellence. What constitutes reliable cross-dating is a moot point and may, perhaps, be largely dependent

[7] A rapid method of correlation for continuous time series. Amer. Journ. Sci., vol. 240, pp. 437-442, 1942.

upon the individual investigator. Here, it is important to know if cross-dating is a prerequisite to the merging of sequences for correlation purposes.

Figure 2 shows the so-called skeleton plots for HPC 1 to 9 and a master plot made by a synthesis of the nine. The heights of the inked lines bear an inverse ratio to the widths of the growth layers on the wood as judged by the eye. No actual measurements enter the skeleton plots. In order to judge the quality of the relationships, the above figure should be compared with figure 3, which shows excellent cross-dating from a forest-border area. The conclusion is obvious: cross-dating as exhibited by the Holman Pass specimens is of remarkably poor quality. One is tempted to say it does not exist at all, for, if the dates were entirely unknown and within a range of several centuries, one would have difficulty in convincing others that the sequences match growth layer for growth layer as they stand. In the present case the validity of the cross-dating, or the only assurance that the growth layers grew on the dates assigned to them on the skeleton plots, rests on two circumstances: (1) the narrowness of the growth layers designated 1880 and 1893 and (2) the probability that the soil moisture in the zone where the trees grew was sufficiently adequate to prevent a temporary halt in growth during any one growing season.

A detailed comparison of the growth layers on all specimens for each date in succession (fig. 2) brings out a lack of correspondence that appears to emphasize a certain degree of individuality in the site factors at each tree.

An analysis of figure 2 was made, and the results were arranged in table 1. The record covers 116 years. Out of this length of record only two cases exist, the growth layers designated 1880 and 1893, wherein the growth layers are notably narrow on the eight specimens bearing them. Two cases, 1836 and 1934, could perhaps be classed with the previous two because the one growth layer that does not conform on each exists on a so-called uniform sequence, one on HPC 7 and the other on HPC 6. Entries in table 1 wherein no narrow growth layer exists on any one of the specimens number 55 cases. With the number of specimens in the count disregarded, there are 22 cases where one growth layer is atypical, 23 cases where two growth layers are atypical, 12 where three are atypical, and 2 where four are atypical. For more than half the years the sequences are from 11 to 50 percent out of agreement with one another.

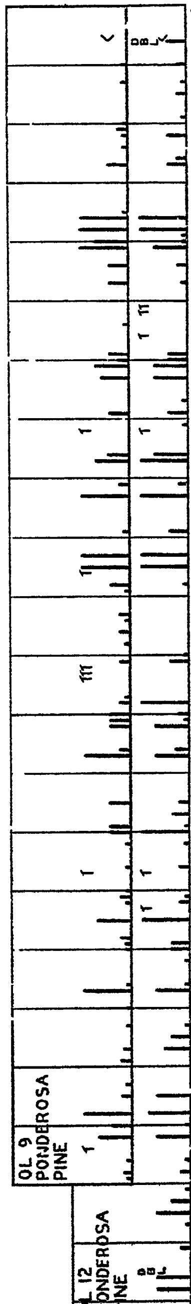

FIG. 3.—Matched skeleton plots showing excellent cross-dating. These represent trees that grew at the forest border in northern Arizona. They should be compared with the poor cross-dating shown on figure 2.

TABLE 1.—*Incidence of growth-layer type*

Analysis of figure 2

	Narrow	Av.	Thick	Dbl.		Narrow	Av.	Thick	Dbl.		Narrow	Av.	Thick	Dbl.
[illegible]	0	4			1871 ..	4	3			1911 ..	0	8	1	
	0	4				0	7				0	8	1	
	0	4				1	3				2	5	2	
	0	4				0	7				0	7	2	
	0	4				1	7				0	9		
	3	1		1		0	8				0	8	1	
	2	2				0	8				4	5		
	0	5				0	7	1			3	6		
	0	5		1		0	8				0	9		
	0	5				8	0				1	7	1	1
1841	0	5			1881	1	7			1921...	0	8	1	
	1	4				2	6		1		7	2		1
	2	4				0	8		1		2	7		
	1	5				0	7	1			0	9		
	1	5				0	8				7	2		1
	1	5				1	7				0	9		
	1	5				0	8				2	7		1
	0	6		1		0	8				3	6		
	0	6				0	8		1		0	9		
	0	6				0	8				2	7		1
1851...	4	2			1891 .	1	7			1931....	1	8		
	2	4				0	9				0	9		
	3	3		1		8	0		1		2	7		
	1	5				0	8				8	1		
	1	5				0	8				0	9		
	0	6				5	3		3		5	4		
	1	6				2	7				1	8		
	0	7				0	7	2			1	8		
	3	4				7	2		1		2	7		1
	2	5				6	3				2	7		
1861..	5	2			1901	0	8	1		1941....	0	7	2	1
	1	6				3	5	1	3		0	9		
	2	5				0	8	1			3	6		
		6				7	2				0	9		
	.	6				2	6	1			2	7		
	0	7		1		0	8	1			6	2	1	
	0	7				0	7	2						
	0	7		1		1	8							
	0	7				0	9							
	3	4				3	6							

NOTES:

1836—an average growth layer on HPC 7, a uniform sequence

1934—an average growth layer on HPC 6, a uniform sequence.

Correlation.—Because of the poor quality of the cross-dating and because of the desire to compare the sequences each with the other based upon precise measurements, the sequences were subjected to statistical correlation. Table 2 gives the trend coefficients and the ratios of opposed to parallel trends for certain trees and certain groups. The bases of selection are evident from the captions in the table.

A comparison of the averages for uniform and variable sequences shows that the uniform have a considerably higher trend coefficient,

TABLE 2.—*Holman Pass collection*

Trend coefficients and ratios of opposed trends

	1850 to 1897		1898 to 1941	
Uniform sequences				
4 vs. 6			0.82	(0.36)
4 vs. 7			0.83	(0.41)
6 vs. 7	0.66	(0.38)	0.57	(0.36)
4 vs. 8			0.88	(0.27)
Variable sequences				
1 vs. 5	0.36	(0.53)	0.73	(0.20)
1 vs. 9	0.32	(0.42)	0.81	(0.23)
5 vs. 9	0.26	(0.42)	0.71	(0.25)
Intergroup				
4 vs. 5	0.90	(0.32)	0.88	(0.20)
4 vs. 9	0.72	(0.36)	0.87	(0.23)
5 vs. 9	0.52	(0.49)	0.76	(0.27)
10 vs. 11	0.94	(0.21)	0.97	(0.14)

	1850 to 1897		1898 to 1941	
Trees east of Pass				
1 vs. 2	0.62	(0.40)	0.90	(0.23)
1 vs. 3	0.86	(0.34)	0.94	(0.20)
1 vs. 4			0.79	(0.32)
2 vs. 3	0.85	(0.30)	0.97	(0.11)
2 vs. 4			0.83	(0.23)
3 vs. 4			0.96	(0.25)
Trees on Pass				
5 vs. 6	0.79	(0.34)	0.91	(0.20)
Trees west of Pass				
7 vs. 8			0.87	(0.23)
7 vs. 9	0.72	(0.40)	0.63	(0.30)
8 vs. 9			0.70	(0.30)

whereas the variable have a very slightly lower trend ratio. If anything, the uniform have a slight advantage.

Intragroup comparisons east of the Pass, on the Pass, and west of the Pass indicate on the whole that correlations are distinctly higher between trees within their own groups than between trees in different groups. If the groups are averaged, this higher correlation is shown even more clearly. Hence, trees grouped together appear to correlate more closely than those rather widely separated.

The matter of distance merits further attention. If the trend ratios of the trees in table 2 are arranged in order of distance within the

group, table 3 results. Among the species, PP means ponderosa pine, FP foxtail pine, WF white fir, and DF Douglas fir. The interval of years in either case ends on 1941. Table 3 is divided into three groups: the first comprising trees east of the Pass, the second on the Pass, and the third west of the Pass.

In general, agreement declines with increasing distance, a distance measured in feet. Site factors at the surface appear to the eye to be nearly identical among the trees of any one group, but apparently the factors do change within short distances in spite of appearances. Proximity outweighs difference of species as well as presence or absence of variability. Factors present at the immediate location of the individual tree, or what may be called microsite factors, appear

TABLE 3.—*H[illegible]man Pass collection*

Ratios of opposed trends

Distance apart	Trees	Species	1898-1941	Total sequence
150 feet	2 vs. 3	PP vs. FP		
	1 vs. 3	PP vs. FP	0.18	0.24
	2 vs. 4	PP vs. WF		
300	1 vs. 2	PP vs. PP	0.24	0.29
	3 vs. 4	FP vs. WF		
450	1 vs. 4	PP vs. WF	0.32	0.34
60 (ca.)	5 vs. 6	DF vs. FP	0.20	0.27
50	7 vs. 8	PP vs. PP	0.23	
230	7 vs. 9	PP vs. PP	0.30	
	8 vs. 9	PP vs. PP		

to exert a strong measure of control on tree growth. That trees separated by a distance of a mile or more do show a parallel agreement of variation in a majority of years indicates the influence of a gross factor uniformly variable within limits over the area. However, when it is remembered that the trend between two growth layers on one tree compared with the trend between two growth layers of the same date on another tree, no matter how remote, can vary only in two directions, parallel or opposite, some allowance must be made for accidental similarities. The same principle, of course, holds true where visual comparisons are made in so-called cross-dating because in the consideration of two growth layers of same date in different trees one growth layer can only be thinner than, thicker than, or of the same thickness as, the other growth layer.

Correlations between groups (table 2) east of Pass, on Pass, and west of Pass are only fair. They show a mixed influence of site and distance. Groups 4 and 5 are relatively close together but have dissimilar sites—they have the highest correlation: groups 4 and 9 are far apart but have somewhat similar sites—they have correlation of intermediate value; and groups 5 and 9 are far apart and have very dissimilar sites—they have the lowest correlation.

Table 2 suggests something much more surprising than the dominant influence of local site factors. The correlation among different trees and among different groups as shown not only by the trend coefficients but also by the trend ratios are distinctly less for the period 1850-1897 than for the period 1898-1941. In fact, a few of the trends, and trend ratios, are of such poor quality as to indicate little relationship. Growth factors from 1850-1897 apparently must have had a localized variability which to a certain extent became less localized after 1897.

For further comparisons among the trees the trends were plotted for each tree against every other tree for the total years of record. A comparison of ponderosa pine with other ponderosa pines, of ponderosa with other species, and of other species among themselves shows that species has no bearing upon the trend agreements. A comparison of sequence types, such as variable with variable, variable with uniform, and the like, shows that the type of sequence being correlated is not an important factor. In general terms, however, the closer two trees are together the greater the number of parallel trends. During the period of 44 years from 1898 to 1941, where all nine trees are in the record, there are 15 years with parallel trends. Agreements are concentrated in the 10-year period, 1920-1929, which has 6 parallel trends. Back of 1898, the period of 48 years adds only 9 parallel trends to the 15 of the later period in spite of the fact that the record of the earlier period contains from one to three fewer trees. The striking lack of agreement prior to 1898 appears to fit in with the lack of correlation mentioned in the paragraph above. Again it seems that the microsite factors may have contrasted more acutely from tree to tree or that an over-all factor exerting a general influence on tree growth may have been more areally variable than later.

Growth-layer characteristics.—Table 4 shows the average of year-to-year variations of growth-layer thicknesses on single tree sequences and on three groups. These figures are the measured equivalents of the visual values embodied in the terms variable, fairly variable, and uniform. In the main, the numerical results militate against judgment by eye. Tree HPC 5, for instance, was judged variable and HPC 6 uniform; yet both have nearly the same average variation. However, greater consistency is shown by groupings: for the period, 1898-1941, the average of the variable sequences is 0.36, of the fairly variable 0.32, and of the uniform 0.28.

Table 4 emphasizes the importance of location, not species, as the apparent determinant of average variation. For instance, trees HPC 3 and 6 are both foxtail pines and yet have variations of 0.37 and

TABLE 4.—*Holman Pass collection*

Average year-to-year variation

		—— to 1897	1898 to 1941	Entire		1850 to 1897	1898 to 1941
HPC 1........	1850–	0.22	0.40	0.30	G 10........	0.26	0.40
2........	1850–	0.35	0.41	0.38	11........	0.38	0.27
3........	1850–	0.31	0.43	0.37	7........	0.21	0.27
4........	1880–	0.36	0.28	0.30			
5........	1850–	0.29	0.19	0.25			
6........	1850–	0.27	0.21	0.24			
7........	1850–	0.18	0.35	0.26			
9........	1857–	0.40	0.39	0.40			

0.24, respectively (0.43 and 0.21 for 1898-1941), the higher value existing in the drier location. It is true that the ponderosa pines have higher variations in general than the other species but HPC 3, a foxtail pine, grew between HPC 1 and 2 and has even a slightly higher average variation.

All trees from the wetter locations (group 11) had higher average variations for the period 1850-1897 than they did for the period 1898-1941. In contrast, the trees in the drier locations (group 10) had lower average variations in the earlier period.

Tables 5 and 6 giving average growth-layer thicknesses and average departures were prepared even though definitive results were not expected because secular trend and long-period fluctuations had not been eliminated. In table 5, group 10 shows an increase and group 11 a decrease of average growth-layer thicknesses from the period 1850-

1897 to that of 1898-1941. The individual trees of group 10 are not consistent among themselves in that HPC 1 and 3 increase decidedly, HPC 2 increases very slightly, and HPC 7 decreases. All trees in group 11 are consistent except for HPC 6 which decreases very slightly. Thus, four trees decrease, two remain practically unchanged, and two increase their average thicknesses for the period 1897-1941 contrasted with that of 1850-1897. Group 7 reflects these influences.

TABLE 5—*Holman Pass collection*

Average growth-layer thicknesses

		—— to 1897	1898 to 1941		1850 to 1897	1898 to 1941
HPC 1........	1850–	1.28	1.82	G 10........	1.53	1.70
2........	1850–	1.87	1.88	11........	2.26	1.96
3........	1850–	1.01	1.23	7........	1.90	1.83
4........	1880–	3.50	2.95			
5........	1850–	1.18	0.79			
6........	1850–	1.52	1.51			
7........	1850–	1.96	1.86			
9........	1861–	2.85	2.61			

TABLE 6.—*Holman Pass collection*

Average departures

		—— to 1897	1898 to 1941		1850 to 1897	1898 to 1941
HPC 1........	1850–	0.31	0.36	G 10........	0.32	0.36
2........	1850–	0.32	0.27	11........	0.34	0.30
3........	1850–	0.45	0.42	7........	0.18	0.20
4........	1880–	0.37	0.36			
5........	1850–	0.39	0.34			
6........	1850–	0.27	0.21			
7........	1850–	0.19	0.38			
9........	1861–	0.31	0.28			

In Table 6, group 10 shows an increase and group 11 a decrease of average departures from the period 1850-1897 to that of 1898-1941. All trees of group 11 are consistent among themselves in the decrease from the earlier to the later period. This is not true for the trees of group 10. Two of them, HPC 2 and 3, actually showed a decrease of average departures and thus conformed with the wet-site trees of group 11. In other words, trees HPC 1 and 7 do not conform with the remaining six trees, yet their influence is sufficiently great to determine the relative values as shown for groups 7 and 10 in table 6.

The data in table 7 were calculated in an attempt to obtain a measure of excess variation over normal. From the earliest to the latest periods shown, HPC 1, 2, 3, and 4 show a rise and decline; HPC 5, 6, and 9 show a general decline; and HPC 7 shows a general rise of values. Six of the trees, but not including HPC 1, have lower values for 1910-1941 than for 1850-1897. As in the case of average departures, it is HPC 1 and 7 which do not conform. In spite of their influence, group 7 shows a slight but progressive decline from the earliest to the latest period. If HPC 1 and 7 are eliminated from group 7, giving group 7 (restricted), the decline becomes more decided.

TABLE 7.—*Holman Pass collection*

Average departure from mean variation

	1850-1897	1898-1941	1910-1941
HPC 1	0.17	0.28	0.24
2	0.21	0.24	0.20
3	0.25	0.26	0.23
4	0.23	0.24	0.21
5	0.20	0.13	0.11
6	0.19	0.16	0.15
7	0.15	0.23	0.24
9	0.28	0.25	0.20
G 10	0.132	0.148	0.136
11	0.204	0.118	0.110
7	0.110	0.105	0.094
7 (restricted)	0.130	0.105	0.092

Table 8 brings together a short summary of characteristics on the wood in order to emphasize the differences between the two periods 1850-1897 and 1898-1941. Although the differences between groups 10 and 11 appear striking, they actually are due to the influence of two out of eight trees. Elimination of those two trees from group 7 brings it into harmony with group 11. There remain, then, the fundamental differences between the periods 1850-1897 and 1898-1941. Do they reflect a change in amount of rainfall with its attendant changes in rainfall characteristics, or a change in the rainfall interval important to tree growth, or both, or some other change? In a previous paragraph a striking dearth of trend agreements among the trees was pointed out for 1850-1897 in contrast with succeeding years. A reexamination of the data shows that the dearth does not apply quite so drastically to the trees from the wetter locations. This

matter of trend agreement appears to be another facet of the general problem brought out by the changes of characteristics on the wood through the years from 1850 to 1941.

TABLE 8.—*Holman Pass collection*

Characteristics

	1850-1897	1898-1941
Average variation		
G 10	0.26	0.40
11	0.38	0.27
7	0.21	0.27
Average thickness		
G 10	1.53	1.70
11	2.26	1.96
7	1.90	1.83
Average departure		
G 10	0.32	0.36
11	0.34	0.30
7	0.18	0.20
Average departure from mean variation		
G 10	0.132	0.148
11	0.204	0.118
7	0.110	0.105

STUDY OF RAINFALL CHARACTERISTICS

Two tasks were set out for consideration in connection with the rainfall data: (1) to determine the interrelationships among the stations of usable records in the vicinity of Holman Pass and (2) to determine the characteristics of those records. As to the first task, it is necessary to know the extent of the differences between two adjacent stations in order to appreciate and allow for the possible differences between the trees and the station nearest to them. As to the second task, it is desired to learn whether or not the rainfall shows any differences between the two periods 1850-1897 and 1898-1941, and, if it does, to compare the differences with those obtained from a study of growth-layer sequences.

Interstation correlations.—Table 9 shows the trend coefficients and ratios of opposed trends between Chacon, the nearest station to Holman Pass, and six other stations for eight selected time intervals. These intervals were chosen on the basis of their possible influence on tree growth. On the whole, the correlations show a remarkable consistency. Those comparisons which do not include part or all of the summer rainfall are commonly higher than those which do. Furthermore, the longer the interval under comparison is, the poorer the correlation in general. Black Lake, the nearest to Chacon in distance as well as elevation, does not have the best correlation with Chacon. Las Vegas has the greatest similarity, a station farther away, 2,100 feet lower, and out beyond the foot of the main range of mountains. Santa Fe rainfall correlates with that of Chacon to a degree equal to the correlation between Black Lake and Chacon. Even Albuquerque is little less in degree of similarity. The best correlations are for the March-April intervals with Black Lake and Albuquerque which show ratios of opposite trends with respect to Chacon of 0.12 and 0.09.

It is scarcely necessary here to do more than refer briefly to the many observations of differences in rainfall at gauges spaced rather closely together. For instance, Stout [8] records a study of July 1948 rainfall on a plot centering at El Paso, Ill. Two stations, 10 miles apart, had 10.44 and 5.93 inches of rainfall. Two other stations, 3 miles apart, showed a difference of 77 percent. Localization of single storms is on occasion even more pronounced. On June 30, 1947, near Lubbock, Tex., 4 to 5 inches of rain fell in a belt about 2 miles wide, whereas none fell 2 miles to the west and 0.26 inches 8 miles to the east. Of course, this may be unusual, but at least it is more or less typical of extreme forest-border conditions.

Furthermore, it must be remembered in comparing tree growth with the rainfall of a station that, as pointed out by Landsberg,[9] a rain gauge samples but does not measure rainfall and therefore "the areal significance of precipitation amounts caught at a station is very restricted. . . ." These characteristics of rainfall must be duly weighed when the growth of selected trees is compared with the record of a station some miles distant. The trees may respond to the rainfall they themselves receive but differ somewhat from that received by the weather station.

[8] Weatherwise, vol. 1, pp. 112-113, 1948.

[9] Landsberg, H., Critique of certain climatological procedures, Bull. Amer. Meteor. Soc., vol. 28, pp. 187-191, 1947.

TABLE 9.—*Correlation between Chacon rainfall and that of other stations*

Trend coefficients and ratios of opposed trends

1909-1941

	Mar.-July	Jan.-Aug.	Mar.-June	May-Aug.	May-June	Jan.-May	Nov.-May	Mar.-Apr.	Av
Black Lake	0.61	0.93	0.93	0.93	0.92	0.88	0.92	0.99	0.89
	(0.41)	(0.22)	(0.28)	(0.28)	(0.16)	(0.19)	(0.19)	(0.12)	(0.23)
Taos	0.86	0.78	0.89	0.87	0.85	0.80	0.86	0.90	0.85
	(0.16)	(0.22)	(0.22)	(0.22)	(0.10)	(0.31)	(0.23)	(0.25)	(0.22)
Taos Canyon	0.92	0.86	0.95	0.86	0.92	0.91	0.94	0.97	0.92
	(0.22)	(0.28)	(0.22)	(0.37)	(0.16)	(0.19)	(0.19)	(0.16)	(0.22)
Las Vegas	0.95	0.91	0.97	0.91	0.87	0.95	0.93	0.97	0.93
	(0.25)	(0.12)	(0.22)	(0.28)	(0.19)	(0.16)	(0.13)	(0.16)	(0.19)
Santa Fe	0.91	0.72	0.98	0.86	0.95	0.86	0.88	0.90	0.88
	(0.25)	(0.31)	(0.12)	(0.34)	(0.12)	(0.22)	(0.23)	(0.22)	(0.22)
Albuquerque	0.89	0.86	0.94	0.66	0.92	0.86	0.78	0.98	0.86
	(0.25)	(0.31)	(0.22)	(0.41)	(0.25)	(0.16)	(0.26)	(0.09)	(0.25)
Average	0.86	0.84	0.94	0.85	0.90	0.88	0.88	0.95	
	(0.26)	(0.24)	(0.21)	(0.32)	(0.18)	(0.19)	(0.19)	(0.16)	

From the qualitative standpoint, the trend ratios of table 9 give a rather clear indication of the amount of agreement to be expected between tree growth and rainfall where the two are as far apart as any two of the rainfall stations. Quantitatively, trend coefficients yield values to be expected in the same fashion. If variations in tree growth mirror variations in rainfall to a high degree then the cor-

TABLE 10.—*Correlation between rainfall intervals at Chacon*

Trend coefficients and ratios of opposed trends

1909-1941

Nov.-May vs. Jan.-Aug.	0.78	(0.26)	Jan.-May vs. Mar.-Apr.	0.02	(0.22)
Nov.-May vs. Jan.-May	0.99	(0.06)	Jan.-May vs. Mar.-June	0.84	(0.22)
Nov.-May vs. Mar.-June	0.82	(0.29)	Jan.-May vs. May-Aug.	0.14	(0.47)
Jan.-Aug. vs. Jan.-May	0.73	(0.28)	Jan.-May vs. May-June	0.18	(0.44)
Nov.-May vs. Mar.-July	0.77	(0.23)	Mar.-July vs. Mar.-Apr.	0.67	(0.31)
Nov.-May vs. May-Aug.	0.21	(0.48)	Mar.-July vs. Mar.-June	0.98	(0.12)
Nov.-May vs. May-June	0.17	(0.45)	Mar.-July vs. May-Aug.	0.85	(0.34)
Nov.-May vs. Mar.-Apr.	0.90	(0.23)	Mar.-July vs. May-June	0.81	(0.22)
Jan.-Aug. vs. Mar.-June	0.87	(0.25)	May-Aug. vs. May-June	0.94	(0.25)
Jan.-May vs. Mar.-July	0.72	(0.22)	May-Aug. vs. Mar.-Apr.	—0.33	(0.66)
Jan.-Aug. vs. Mar.-July	0.97	(0.22)	May-Aug. vs. Mar.-June	0.66	(0.44)
Jan.-Aug. vs. May-Aug.	0.92	(0.25)	May-June vs. Mar.-Apr.	—0.02	(0.47)
Jan.-Aug. vs. May-June	0.69	(0.22)	May-June vs. Mar.-June	0.87	(0.25)
Jan.-Aug. vs. Mar.-Apr.	0.56	(0.38)	Mar.-Apr. vs. Mar.-June	0.90	(0.25)

relation between Holman Pass trees and Chacon rainfall should closely approach or possibly equal the average values set out in table 9. Should this prove to be true, the conclusion is no doubt justified that trees growing in a zone well above critical moisture conditions rather faithfully record rainfall variations at the site from year to year, barring the impact of an "accidental" factor in concentrated form in any one year.

Table 10 sets forth correlations between various month-intervals in

Chacon rainfall. Good correlations in general result under three circumstances: In the lack of summer rainfall in the intervals compared, in the proportion of overlap between the two intervals, and in the length of the intervals. For instance, November-May versus January-May has a trend coefficient of 0.99 and a trend ratio of 0.06 whereas, contrariwise, May-August versus March-April has values of −0.33 and 0.66. The table as a whole shows great variation and indicates the necessity of comparing tree growth with different rainfall intervals. It goes farther than this. If tree growth is found to correlate with one particular month-interval, then a great quantity of xylem (as a thick growth layer) formed during a certain season suggests copious rainfall for that month-interval; it does not necessarily suggest that the entire year is a wet one.

Rainfall characteristics.—For a study of the influence of a single factor, such as rainfall, on tree growth it is necessary to have long records at the immediate site of the trees. Short records taken a matter of several miles distant can be highly indicative but not necessarily conclusive. In the present case the record at Chacon, 7 miles away, begins with 1909. Therefore, the longer records of Santa Fe and Albuquerque were used, in spite of greater distances, in order to determine possible differences in rainfall characteristics between the periods 1850-1897 and 1898-1941.

Table 11, in the first place, gives the March-July and January-August rainfall for 1909-1941 at the several stations. As will be shown later, the rainfall of March-July is a significant factor in tree growth. In the second place, table 11 gives the rainfall of Santa Fe and Albuquerque for the periods 1850-1897 and 1898-1941 set out for various month-intervals. Two points must be considered. First, there is the striking fact that the average rainfall of March-July for both Santa Fe and Albuquerque was less during the period 1850-1897 than during that of 1898-1941. The same is true for the average rainfall of Albuquerque for January-August. Second, there is the fact that the average rainfall of January-August at Santa Fe was greater during 1850-1897 than for the following 44 years. The reason for this inconsistency with the intervals mentioned in the first point above was suspected as soon as it was determined that the average rainfall of January-May, in contrast to the rainfall of January-August, was less during the earlier period, 1850-1897. Therefore, the average rainfall was computed for March-April, May-June, April, May, June, July, August, and September. Only July and August showed greater

average rainfall for 1850-1897 than for 1898-1941. It was obvious at once that the greater rainfall of August aided by that of July caused the greater average rainfall of January-August during 1850-1897 at Santa Fe. In September, as a matter of interest, the averages swing back so that the figures are 1.58 inches for 1850-1897 and 1.66 inches

TABLE II.—*Average rainfall (inches)*

	March-July 1909-1941	January-August 1909-1941
Chacon	10.34	15.80
Black Lake	8.42	12.66
Taos	5.96	8.83
Taos Canyon	9.64	14.68
Las Vegas	9.33	13.66
Santa Fe	6.88	10.14
Albuquerque	4.24	6.28

	Santa Fe		Albuquerque	
	1850-1897	1898-1941	1850-1897	1898-1941
March-July	6.34	6.74	3.16	3.97
January-August	10.60	10.11	5.60	5.92
January-May	3.94	4.82	1.75	2.50
March-April	1.54	1.92	0.58	1.07
May-June	2.14	2.61	1.26	1.43
April	0.71	1.08	0.29	0.67
May	0.99	1.19	0.36	0.73
June	1.15	1.18	0.79	0.69
July	2.66	2.21	1.37	1.47
August	2.89	1.90	1.59	1.26
September	1.58	1.66	0.90	0.98

Albuquerque, 1850-1897, 27 years of record only.

for 1898-1941. This situation no doubt should be given emphasis: the average rainfall for the interval March-June began to increase somewhere near 1898 whereas that for the interval July-August decreased. Calculation shows that the average for March-June began to increase slowly just before the turn of the century and that the increase accelerated after 1909. The simultaneous increase and decrease of two sequential month-intervals is a point of importance in relation to the period of greatest tree growth within the season.

Table 12 gives the average year-to-year variation of rainfall arranged in two parts, the first of which sets out the variations of March-July and January-August rainfall for the period 1909-1941 at the several stations. In view of the differences in elevation, the average variation of the rainfall is of the same order of magnitude

TABLE 12.—*Rainfall*

Average year-to-year variation

	March-July 1909-1941	January-August 1909-1941
Chacon	0.36	0.26
Black Lake	0.38	0.29
Taos	0.36	0.25
Taos Canyon	0.28	0.22
Las Vegas	0.41	0.34
Santa Fe	0.35	0.27
Albuquerque	0.63	0.45

	Santa Fe 1850-1897	Santa Fe 1898-1941	Albuquerque 1850-1897	Albuquerque 1898-1941
March-July	0.42	0.33	0.79	0.60
January-August	0.39	0.27	0.63	0.44

TABLE 13.—*Rainfall*

Average departures

	March-July 1909-1941	January-August 1909-1941
Chacon	0.22	0.17
Black Lake	0.25	0.19
Taos	0.27	0.20
Taos Canyon	0.20	0.17
Las Vegas	0.30	0.26
Santa Fe	0.24	0.20
Albuquerque	0.43	0.31

	Santa Fe 1850-1897	Santa Fe 1898-1941	Albuquerque 1850-1897	Albuquerque 1898-1941
March-July	0.33	0.22	0.58	0.40
January-August	0.30	0.19	0.45	0.30

as that of the Holman Pass trees. The second part of the table shows the average variation of 1850-1897 to be greater than that of 1898-1941, which is no doubt to be expected because of the lower average rainfall of the earlier period. Even the interval January-August at Santa Fe has the same decrease in the later period.

Table 13 gives average rainfall departures. In the first portion of the table the departures for the rainfall of March-July and January-

August during the period 1909-1941 are given for the several stations. These average departures are noticeably less than the comparable values for the growth layers of the Holman Pass collection. In the second portion of the table the average departures of the period 1850-1897 are distinctly higher than those of the period 1898-1941. The contrast between the two periods stands thus: a lower average

TABLE 14.—*Holman Pass tree growth and Santa Fe rainfall—characteristics*

	1850-1897	1898-1941
Average magnitude		
Rainfall (inches)	6.34	6.74
Growth layers (mm.)		
G 10	1.53	1.70
11	2.26	1.96
7 (restricted)	1.99	1.83
Average variation		
Rainfall	0.42	0.33
Growth layers		
G 10	0.26	0.40
11	0.38	0.27
7 (restricted)	0.33	0.32
Average departure		
Rainfall	0.33	0.22
Growth layers		
G 10	0.32	0.36
11	0.34	0.30
7 (restricted)	0.35	0.31
Average departure from mean variation		
Rainfall	0.25	0.22
Growth layers		
G 10	0.132	0.148
11	0.204	0.118
7 (restricted)	0.130	0.105

rainfall during the earlier period is accompanied by a higher average variation and by a higher average departure. On the whole, such characteristics are to be expected.[10]

There remains, then, a comparison between the characteristics of the growth layers and those of rainfall for which the records of Santa Fe are used because of their length and continuity. Table 14 makes

[10] Mixer, C. A., The rainfall year, Bull. Amer. Meteor. Soc., vol. 15, pp. 22-23, 1934; Williamson and Clark, Variability of annual rainfall in India, Geogr. Rev., vol. 21, pp. 675-676, 1931.

these comparisons using March-July rainfall. An increase in average rainfall (as between 1850-1897 and 1898-1941) is accompanied by an increase of average growth-layer thickness on dry sites (group 10) and by a decrease on wet sites (group 11); an increase in rainfall giving a decrease in its average variation is accompanied by an increase of average variation among growth layers from dry sites and by a decrease among growth layers from wet sites; an increase in rainfall giving a decrease in its average departure is accompanied by an increase of average departure among growth layers from dry sites and by a decrease among growth layers from wet sites; and an increase in rainfall giving a decrease in its average departure from mean variation is accompanied by an increase of average departure from mean variation among growth layers from dry sites and by a decrease among growth layers from wet sites.

In other words, changes of average variation, average departure, and average departure from mean variation among growth layers from wet sites follow the changes of the same features in the rainfall whereas the growth layers from dry sites react in the opposite direction. The case is reversed as regards changes in growth-layer thicknesses: the growth layers from the dry sites follow the changes in average rainfall amounts. However, as discussed under the study of growth layers, two trees, HPC 1 and 7 of group 10, determine the characteristics of the group. Their elimination from the complete record leaves a homogeneous group consisting of the other two trees of group 10 and all trees of group 11 (HPC 8 is not included because its sequence is too short). This group of six trees, group 7 (restricted), is conformable within itself, and the changes in its characteristics from 1850-1897 to 1898-1941 agree with those of Santa Fe rainfall.

Nevertheless, there remains the problem of why the average variation of the dry-site trees increased with a decrease of average variations in rainfall during 1898-1941. Calculation of the average variation of rainfall for different months and month-intervals shows that only April and May increased their average variations during the period 1898-1941. It might be, therefore, that the dry-site trees were more influenced by April-May, or spring, rainfall than the wet-site trees were. Or the problem may concern limiting factors and optimum or near optimum soil-moisture conditions in that the wet-site trees grew under conditions where the trees responded directly and consistently to changes in rainfall.

It is clear that the relations of tree growth to rainfall are highly complex not by themselves alone but also by the interplay of the entire range of growth factors, a circumstance emphasized by plant physiologists and ecologists.[11] The problem calls for much more work—it is far from finished. The observational method of field selection and laboratory analysis remains secondary to direct experiment on growing trees under controlled conditions.

In any event, the present work comparing tree growth and rainfall characteristics strongly suggests that trees selected from certain sites and from the proper rainfall or soil-moisture zone can be sensitive indicators of rainfall changes through the use of average variation, average departure, and average departure from mean variation.

CORRELATION OF TREE GROWTH AND RAINFALL

Range of tests.—Fairly extensive correlations were made between tree growth and Chacon and Santa Fe rainfall both for groups and for individual trees. The trend method was applied in its complete form until it was determined that variations of 1 or 2 years did not unduly distort the results. In addition to the more extensive correlations, selected tests were made between tree growth and the records of other rainfall stations.

Tree growth (groups) and Chacon rainfall.—Groups 1 to 9 were correlated with Chacon rainfall for the month-intervals shown in table 15. However, the table includes only those groups which were most significant.

The table shows that correlations with March-July and January-August rainfall are the highest, and of these two intervals March-July is the more important. July rainfall is necessarily included as is indicated by the lower correlations of March-June. Of the 5 months, March-July, the rainfall of May-June is more important to tree growth than that of March-April and the rainfall of April is of less importance than that of May, June, or July. Apparently tree growth, as represented by the trees selected, responds directly to the rain which falls during and the several weeks immediately preceding the actual growing season.

The most striking fact obvious at first sight is the correlation between group 7 (all trees) and March-July rainfall, the trend coefficient being 0.965 and the ratio of opposed trends 0.12. A trend ratio of 0.12 means that the trend of rainfall was opposite to the trend

[11] Bot. Rev., vol. 7, pp. 651-655, 1941.

of tree growth for 4 years out of 32 of variation. Of these opposite trends that for 1910 contains 84 percent of the numerical disagreement and, if 1910 be eliminated, the trend coefficient rises to 0.994. A comparison of the rainfall among all seven stations with the tree growth of group 7 for the 4 years of opposite trend, 1910, 1912, 1913,

TABLE 15.—*Correlation of tree groups and Chacon rainfall*

Trend coefficients and ratios of opposed trends
1909-1941

	G 4	G 5	G 7	G 9	G 10	G 11
Mar.-July	0.93	0.82	0.965	0.88	0.96	0.92
	(0.22)	(0.31)	(0.12)	(0.19)	(0.16)	(0.22)
Jan.-Aug.	0.92	0.73	0.95	0.88	0.94	0.91
	(0.16)	(0.31)	(0.19)	(0.25)	(0.22)	(0.28)
Mar.-June	0.85	0.82	0.89	0.77		
	(0.28)	(0.28)	(0.16)	(0.28)		
May-Aug.	0.80	0.68	0.80	0.66		
	(0.25)	(0.37)	(0.28)	(0.28)		
May-June	0.73	0.70	0.72	0.49		
	(0.31)	(0.34)	(0.28)	(0.34)		
Jan.-May	0.72	0.32	0.70	0.62		
	(0.25)	(0.44)	(0.28)	(0.41)		
Nov.-May	0.71	0.26	0.68	0.59		
	(0.23)	(0.42)	(0.26)	(0.39)		
Mar.-Apr.	0.50	0.44	0.55	0.52		
	(0.41)	(0.44)	(0.37)	(0.50)		
May-July	0.84	0.71	0.85	0.71		
	(0.22)	(0.31)	(0.19)	(0.25)		
April	0.04	0.20	0.09	0.14		
	(0.47)	(0.47)	(0.56)	(0.56)		
May	0.75	0.34	0.64	0.27		
	(0.25)	(0.44)	(0.34)	(0.41)		
June	0.42	0.79	0.59	0.54		
	(0.47)	(0.25)	(0.37)	(0.44)		
July	0.62	0.48	0.66	0.63		
	(0.41)	(0.50)	(0.37)	(0.37)		
August	0.39	0.33	0.35	0.27		
	(0.37)	(0.44)	(0.41)	(0.41)		

and 1931, shows that from one to three stations disagree with the remainder in each case. The 5 years of greatest parallel variation in the complete record have only one station disagreeing with the remainder for 1 year. Where the parallel variations are of small amount the different rainfall stations are much at variance with each other for all years. Therefore, it is possible to speculate that the rainfall at the site of the trees actually agreed with tree growth; however,

the data at Chacon are the closest legitimate record and must be retained as they stand.

The quality of the correlation between tree growth and March-July rainfall at Chacon for the 33-year interval (table 15) is all that can be ecologically expected considering the distance between Holman Pass and Chacon, and considering the quality of the correlations between the rainfall of two stations approximately as far apart as Holman Pass and Chacon. This suggests that the trees as a group follow with a high degree of accuracy the fluctuations of rainfall at the immediate site.

In general, group 7 shows slightly higher correlations than the others and group 5 slightly less; otherwise there is little choice among them. Group 4, the closest to Chacon, has a very slight advantage over group 9, and both have higher correlations than group 5, which is ecologically less similar to the other two than they are between themselves. In the case of groups 10 and 11, the former (from the drier sites) has a slightly higher correlation than the latter although not sufficiently so to justify any conclusions. Group 7, containing all trees, possesses slightly better correlation than group 7 (restricted), the values for March-July being 0.95 and (0.28) and for January-August 0.94 and (0.19).

Figure 4 shows Chacon rainfall for March-July compared with tree growth of the several pertinent groups.

The charted correlations of group 7 with Chacon rainfall in figure 6 indicate in general that the absence of summer rainfall and the presence of winter rainfall militate against high agreement. It is neither spring rainfall alone nor spring combined with winter rainfall which gives highest correlations but spring added to early and midsummer rainfall.

Tree growth (individual trees) and Chacon rainfall.—Individual trees were correlated with the two rainfall intervals of March-July and January-August (table 16). The results are to be expected, no doubt, in view of the former group correlations. In general, the trees agree a little better with March-July than with January-August rainfall. Tree HPC 3, a foxtail pine, has the highest correlation and HPC 9, a ponderosa pine, has the lowest. However, HPC 5, a Douglas fir, runs a close second to HPC 9. As a matter of fact, tree HPC 3, which stands between HPC 1 and 2, could be used as a fair substitute for group 7. Ponderosa pines have no advantage over the other species. On the whole, the trees east of the Pass correlate better than those on the Pass and these latter slightly better than those

TABLE 16.—*Correlation of Holman Pass trees and Chacon rainfall*

Trend coefficients and ratios of opposed trends

1909-1941

	March-July	January-August
HPC 1	0.92	0.90
	(0.25)	(0.31)
2	0.89	0.90
	(0.25)	(0.25)
3	0.92	0.92
	(0.19)	(0.12)
4	0.89	0.83
	(0.25)	(0.25)
5	0.81	0.68
	(0.34)	(0.41)
6	0.78	0.77
	(0.31)	(0.31)
7	0.90	0.87
	(0.22)	(0.34)
8	0.88	0.90
	(0.22)	(0.22)
9	0.51	0.62
	(0.28)	(0.34)

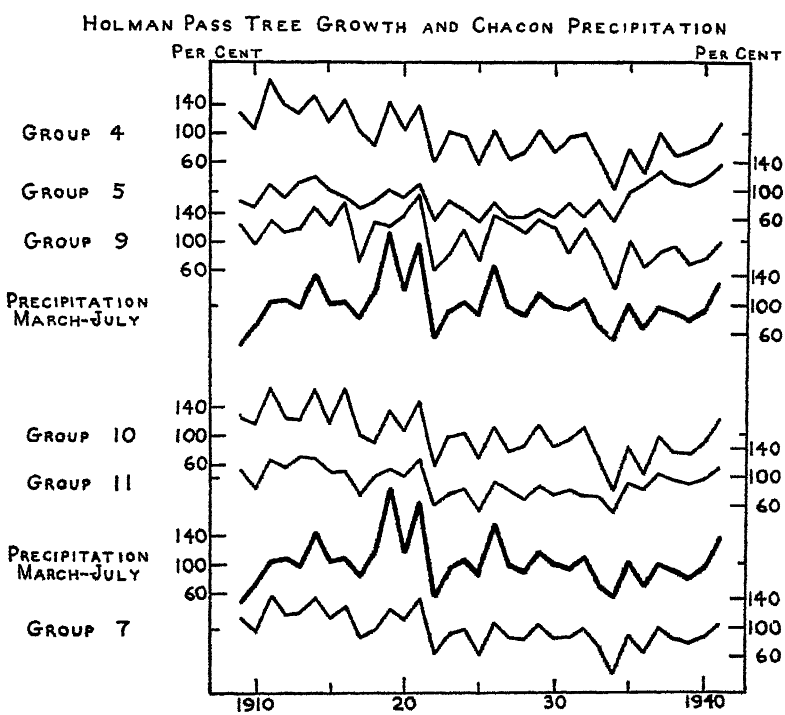

FIG. 4.—Graphs of tree growth and rainfall 7 miles distant, in raw percentages. Group 4, east of Pass; group 5, on Pass; group 9, west of Pass; group 10, normal or dry-site trees; group 11, wet-site trees; and group 7, all trees.

west of the Pass although there are individual exceptions. The most striking contrast appears between the trees from the drier sites, group 10, and those from the wetter, group 11.

In summary, it is rather clearly evident, first, that a group is superior to single trees for a record of rainfall variations and, second, that the variations shown among the trees in table 16, especially in the ratios of opposed trends, emphasize the influence of what has previously been referred to as microsite factors. A union of several tree records apparently generalizes the record of response to rainfall. When consideration is given the facts that the trees do differ from each other by an amount to be expected over a short term, in view of the variations among different rainfall records themselves; that the trees are several miles from Chacon; that rainfall is but one growth factor in a complex; and that rainfall itself is rather remote from its incorporation into the hydrostatic system of the plant, the correlations not only between rainfall and tree groups but also between rainfall and individual trees are surprisingly high for the period 1909-1941.

Tree growth (groups) and the rainfall of other stations.—Certain groups were correlated with the rainfall of the stations at Black Lake, Taos Canyon, Taos, and Albuquerque. The results for four of the groups are shown in table 17. Before continuing it should be mentioned that these particular correlations were not included to demonstrate that tree growth can be compared to distant rainfall with significant results or to indicate favor for such correlations. They are shown rather because they appear to indicate that detailed influence of specific rainfall subsides with distance and only general variations common to the region remain. With ratios of opposed trends ranging from 0.22 to 0.50, tree growth in one locality gives a poor picture of rainfall variations at a distance.

On the one hand, correlations with March-July rainfall, the best in the case of Chacon, are mixed and poor; it is difficult to read any significance into them. On the other hand, correlations with the more general interval of January-August rainfall are higher and more consistent and emphasize the regional regime. Even so, the number of instances in which the trees respond in a direction opposite to the rainfall trends militates against the use of tree growth, as exemplified by the Holman Pass collection, for an accurate gauge of regional rainfall variations from season to season. This is not to say that smoothing would not bring out general trends if the influence of other

TABLE 17.—*Correlation of tree groups and rainfall*

Trend coefficients and ratios of opposed trends
1909–1941

	G 4		G 5		G 9		G 7	
	Mar.-July	Jan.-Aug.	Mar.-July	Jan.-Aug.	Mar.-July	Jan.-Aug.	Mar.-July	Jan.-Aug.
Black Lake	0.32	0.78	0.36	0.75	0.33	0.80	0.37	0.86
	(0.41)	(0.31)	(0.44)	(0.34)	(0.50)	(0.28)	(0.44)	(0.22)
Taos Canyon	0.79	0.79	0.79	0.71	0.75	0.89	0.84	0.89
	(0.37)	(0.28)	(0.31)	(0.38)	(0.41)	(0.28)	(0.34)	(0.22)
Taos	0.74	0.65	0.62	0.66	0.66	0.80	0.79	0.80
	(0.25)	(0.31)	(0.34)	(0.34)	(0.28)	(0.28)	(0.22)	(0.28)
Albuquerque	0.77	0.86	0.79	0.81	0.61	0.77	0.81	0.88
	(0.28)	(0.28)	(0.28)	(0.41)	(0.37)	(0.37)	(0.31)	(0.31)

factors were eliminated and if the trees were properly selected from the region and from the proper zone.

Further to test the general relationships, the March-July and January-August rainfall of Chacon, Las Vegas, Taos Canyon, and Black Lake were combined for the period 1909-1941 and correlated with group 7. The results follow.

	Raw percentages	Smoothed percentages
March-July	0.95	0.96
	(0.19)	(0.22)
January-August	0.96	0.86
	(0.16)	(0.31)

Although these values are high no advantage results from the use of the combined rainfall. The raw percentage values for group 7 (restricted) correlated with combined rainfall of March-July are 0.955 and (0.22), and of January-August rainfall 0.955 and (0.12).

An analysis of table 17 shows, further, that altitude in general has some effect: the correlations are slightly higher for group 9, which is closer to the average elevation of the rainfall stations.

TABLE 18.—*Correlation of tree groups and Las Vegas rainfall*

Trend coefficients and ratios of opposed trends

	March-July		January-August	
	1893-1941	1910-1941	1893-1941	1910-1941
G 4	0.78	0.93	0.73	0.89
	(0.33)	(0.28)	(0.20)	(0.16)
5	0.73	0.81	0.66	0.73
	(0.31)	(0.27)	(0.22)	(0.22)
9	0.59	0.64	0.63	0.63
	(0.47)	(0.44)	(0.39)	(0.37)
7	0.79	0.91	0.73	0.86
	(0.35)	(0.31)	(0.27)	(0.25)

Trees HPC 3, 5, 7, and 9 were correlated with the stations listed in table 17. The results are similar to those for the groups in the table except for somewhat lower values.

Tree growth and Las Vegas rainfall.—With the exception of Santa Fe, Las Vegas has the longest rainfall record of any station in the general area but it is some 37 miles distant from Holman Pass and 3,000 feet lower. Table 18 gives the trend coefficients and the ratios of opposed trends between tree growth and Las Vegas rainfall for the intervals and years noted. On the whole, the correlations

with March-July rainfall slightly exceed those with January-August. They decrease in quality with distance; that is, correlations of group 4 (east of Pass) are highest and those of group 9 (west of Pass) are lowest.

The most striking feature of the table is the decided increase in correlation of the period 1910-1941 over the period 1893-1941. During the later period (1910-1941) the trees follow more closely the variations in rainfall as recorded at Las Vegas.

Tree growth and Santa Fe rainfall.—Although Santa Fe is distant some 40 miles from Holman Pass it is worth while, because of the length of record, to compare Santa Fe rainfall with tree growth in order to determine if the quality of correlation varied throughout the length of that record. Nine tree groups were correlated with all rainfall intervals for the periods 1850-1897 and 1898-1941 separately.

Data most pertinent to the study appear in table 19, which gives the trend coefficients and ratios of opposed trends for the periods mentioned above. The remainder of the data, not shown, simply corroborate what the table itself shows. On the whole, tree growth correlates considerably better with March-July than with January-August rainfall. Here, however, in contrast with Chacon rainfall, groups 4, 5, and 7 agree somewhat better with March-June rainfall.

General correlations are fair; they possess little value except to show a regional tendency toward similarity during a portion of the years. This appears in table 20 where trend coefficients for the period of 1850-1941 vary from 0.52 to 0.67 and the ratios of opposed trends from 0.24 to 0.37. The values for group 7 are 0.65 for the trend coefficient and 0.35 for the ratio of opposed trends. Thus, a case of 35 opposite trends against 65 parallel gives neither high nor dependable correlation. Surprisingly, the trees from the wetter sites, group 11, compare most favorably with Santa Fe rainfall for the period 1850-1941. In view of the quality of correlation between Holman Pass tree growth and Chacon rainfall on the one hand and between Chacon and Santa Fe rainfall on the other, the correlation between tree growth and Santa Fe rainfall possesses values consistent with the relative distances.

Figure 5 shows Santa Fe rainfall for March-July compared with tree growth of the several pertinent groups. Figure 6 shows the correlations in charted form. For the period 1898-1941 the trend of the graph resembles that for the Chacon correlations. It contrasts notably with the graph for the period 1850-1897, where the emphasis seems to be on spring rainfall.

TABLE 19.—*Correlation of tree groups and Santa Fe rainfall*

Trend coefficients and ratios of opposed trends

	G 4		G 5		G 9		G 7	
	1850-97	1898-1941	1850-97	1898-1941	1850-97	1898-1941	1850-97	1898-1941
Mar.-July	0.51	0.67	0.36	0.83	0.44	0.70	0.51	0.77
	(0.47)	(0.27)	(0.40)	(0.20)	(0.40)	(0.32)	(0.43)	(0.27)
Jan.-Aug.	0.24	0.70	0.01	0.77	0.05	0.76	0.12	0.86
	(0.47)	(0.34)	(0.49)	(0.25)	(0.49)	(0.30)	(0.51)	(0.25)
Mar.-June	0.61	0.67	0.53	0.79	0.45	0.62	0.64	0.73
	(0.40)	(0.27)	(0.30)	(0.23)	(0.42)	(0.32)	(0.32)	(0.27)
May-Aug.	0.09	0.72	0.10	0.67	0.00	0.64	0.04	0.79
	(0.60)	(0.32)	(0.49)	(0.23)	(0.51)	(0.32)	(0.55)	(0.23)
May-June	0.38	0.68	0.47	0.70	0.16	0.59	0.40	0.72
	(0.45)	(0.39)	(0.34)	(0.30)	(0.40)	(0.39)	(0.36)	(0.34)
Jan.-May	0.51	0.61	0.21	0.72	0.18	0.58	0.35	0.62
	(0.40)	(0.18)	(0.38)	(0.20)	(0.47)	(0.27)	(0.43)	(0.23)
Nov.-May	0.36	0.68	0.04	0.73	0.12	0.60	0.17	0.69
	(0.27)	(0.16)	(0.37)	(0.23)	(0.39)	(0.34)	(0.39)	(0.25)
Mar.-Apr.	0.52	0.32	0.30	0.44	0.63	0.34	0.61	0.34
	(0.36)	(0.39)	(0.34)	(0.41)	(0.45)	(0.48)	(0.32)	(0.50)

The most important, perhaps, and certainly the most startling information yielded by tables 19 and 20 is the great increase in the quality of correlation from the period 1850-1897 to the period 1898-1941. Table 20 shows this in abbreviated form for March-July rainfall, which appears to have most influence on tree growth. In addition, table 20 includes the period 1910-1941. It is to be noted that correlation is higher for 1910-1941 than for 1898-1941; in other words, there is a general increase in correlation toward recent years. Of all the groups, numbers 5 and 11, containing trees from the wetter sites, show not only the greatest increases but also the highest correlations for the periods 1898-1941 and 1910-1941. And of these two groups, number 5, composed of trees on the Pass, exceeds even group 11. Group 10, in contrast, containing trees from the drier sites, and group 4 exhibit the least increases. Table 11, giving the March-July rainfall of Santa Fe for the periods 1850-1897, 1898-1941, and 1910-1941, shows the rainfall to have been 6.34, 6.74, and 6.88 inches, respectively, for those periods. Furthermore, the low incidence of parallel trends, growth layer to growth layer, among the trees prior to 1897 as compared with the years following 1897 (as noted above under study of growth layers), and the lower correlations between trees and groups (table 2), suggest emphatically that the above phenomena are closely related.

TABLE 20.—*Correlation of tree groups and Santa Fe rainfall*

Trend coefficients and ratios of opposed trends
March-July rainfall

	1850-1897	1898-1941	1910-1941	1850-1941
G 4	0.51	0.67	0.77	0.61
	(0.47)	(0.27)	(0.22)	(0.37)
5	0.36	0.83	0.87	0.52
	(0.40)	(0.20)	(0.16)	(0.31)
9	0.44	0.70	0.71	0.58
	(0.40)	(0.32)	(0.25)	(0.36)
7	0.51	0.77	0.85	0.65
	(0.43)	(0.27)	(0.22)	(0.35)
10	0.51	0.69	0.76	0.62
	(0.43)	(0.25)	(0.19)	(0.34)
11	0.42	0.81	0.90	0.67
	(0.38)	(0.30)	(0.22)	(0.24)
7 (restricted)	0.46	0.82	0.89	0.63
	(0.45)	(0.27)	(0.22)	(0.36)

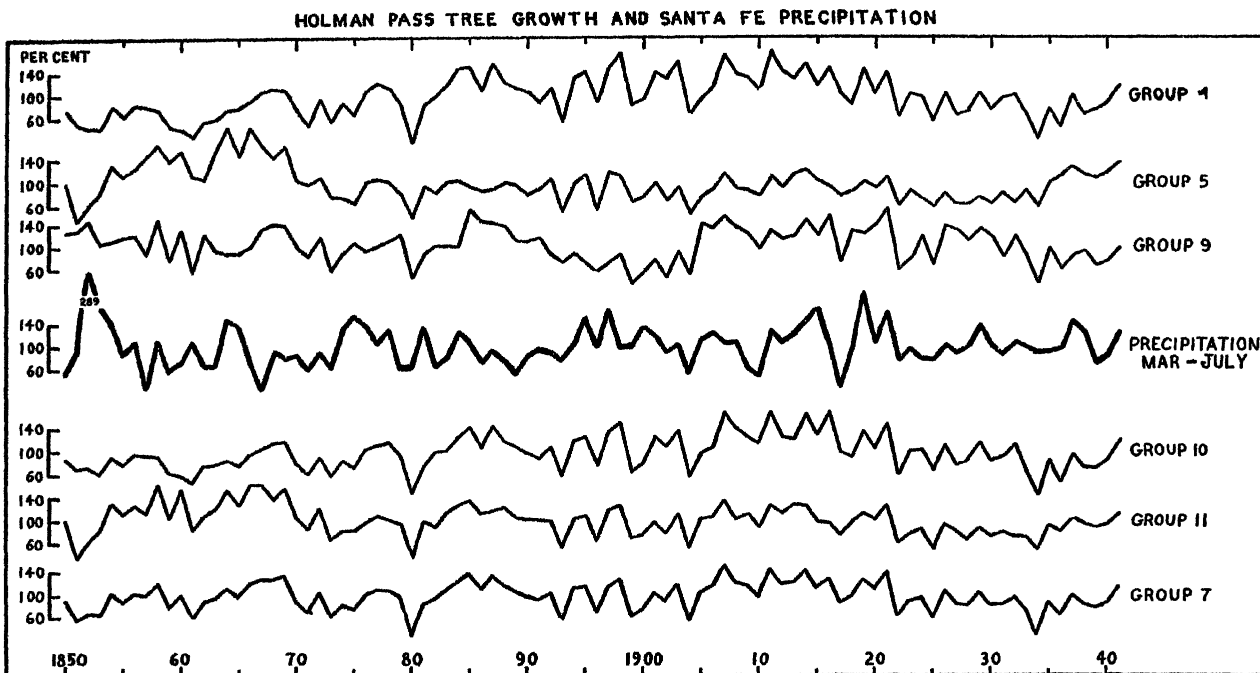

FIG. 5.—Graphs of tree growth and rainfall 40 miles distant, in raw percentages. Group 4, east of Pass; group 5, on Pass; group 9, west of Pass; group 10, normal or dry-site trees; group 11, wet-site trees; and group 7, all trees

Table 19, as stated heretofore, shows a higher correlation for 1898-1941 than for 1850-1897. This is true for all month-intervals except for March-April which has lower correlations in groups 4, 7, and 9 for 1898-1941. Apparently March-April rainfall had greater influence on tree growth during the earlier period than during the later. Group 5 did not conform except in the ratio of opposed trends. An examination of the temperature records readily available gives table 21.

Obviously, a thermochemical or thermophysiological approach to temperature problems via direct experimental evidence in conjunction

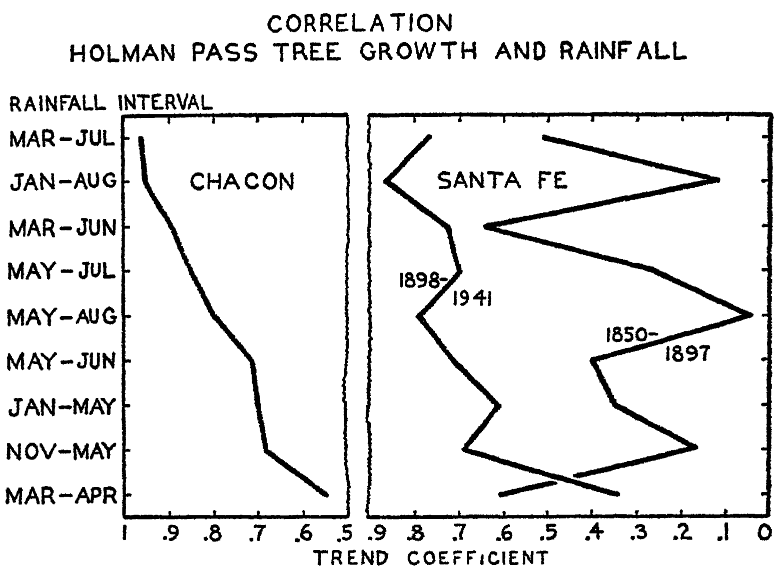

FIG. 6.—Charted correlations between tree growth of group 7 and rainfall of various month intervals.

with exact knowledge of growth initiation would give a much better idea of relationships among temperature, soil moisture, and growth. However, table 21 shows that for March, April, and May the average temperatures and the average maxima were somewhat higher for the period 1874-1897 and progressively lower thereafter except in the case of May when they were slightly higher again during 1910-1930. June follows the same pattern but in a less decided fashion. It is perhaps not illogical to speculate that with higher temperatures during 1874-1897 growth began earlier in the spring and was therefore influenced by March-April rainfall to a greater extent than after 1897. This may be linked up with the discussion, under the preceding section, of the parallel increase of average variation in dry-site trees and

April-May rainfall for the period 1898-1941 over that of 1850-1897. Again, figure 6, showing the charted correlations of group 7 with Santa Fe rainfall for 1850-1897, shows the emphasis to be on spring rainfall. These relationships emphasize the multiple nature of growth factors and the complexity of the problems involved.

Before the contrasts between the periods 1850-1897 and 1898-1941 are summarized, mention should be made of two points, one having to do with the incidence of opposed trends and the other with cumulative variations. First, the incidence of opposed trends was calculated for each 10-year interval for several of the groups against the various rainfall intervals. In the case of groups 7, 10, and 11 compared with March-July rainfall the incidence of opposed trends shows a general decline from early to recent years. The same is

TABLE 21.—*Santa Fe temperatures*

	1874-1897	1898-1930	1910-1930
March			
Average	39.9	39.4	39 0
Maximum	51.4	50.5	50.1
Minimum	28 0	28.4	27.9
April			
Average	47.4	46.75	46.5
Maximum	60.0	58.45	58.2
Minimum	34.76	35.1	34.8
May			
Average	56.5	55.1	55.5
Maximum	69.4	67.2	67.7
Minimum	43.5	43.0	43.3

true, in fact, for all rainfall intervals except that for March-April in which the incidence increases from 1850 to 1941, thus agreeing with the decrease of tree growth-rainfall correlation. Second, figure 7 gives the plotted cumulative variations of Santa Fe March-July rainfall and certain tree groups. Groups 5 and 11 and groups 4 and 10 were each combined into one graph because the separate graphs very nearly coincided. If groups 4 and 5 had been omitted there would have been no change. The graphs illustrate the close correspondence between the variations of Santa Fe rainfall and the variations of tree growth as represented by group 11 which contains the trees from the wetter sites.

The various tables have brought out the contrasts between the periods 1850-1897 and 1898-1941. These may now be summarized in respect to March-July rainfall at Santa Fe. In so far as data are

available, the rainfall records of Albuquerque and Las Vegas corroborate the results obtained by the use of Santa Fe rainfall.

For the rainfall of the period 1898-1941, against the period 1850-1897: amount of rainfall increased; and average variation, average departure, and average departure from mean variation decreased.

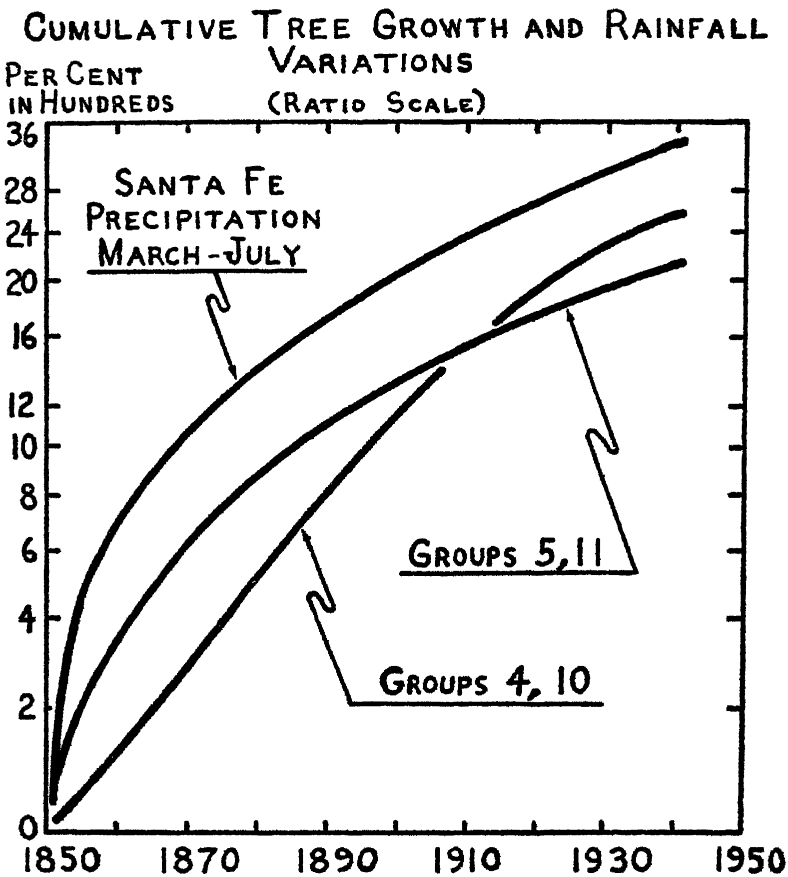

FIG. 7.—Cumulative variations of tree growth and rainfall. Trees in groups 5 and 11 were from wet sites and those in groups 4 and 10 chiefly from dry sites.

For group 11 contrasted in the same manner: average variation, average departure, and average departure from mean variation decreased; and correlation with rainfall increased to an extent comparable to that with Chacon rainfall considering the much greater distance.

For group 10 contrasted in the same manner: average variation, average departure, average departure from mean variation, and correlation with rainfall increased.

For group 7 contrasted in the same manner: average variation and average departure increased; average departure from mean variation decreased very slightly; correlation with rainfall increased; and internal agreement of the trends among the several trees increased.

For group 7 (restricted) contrasted in the same manner: average variation, average departure, and average departure from mean variation decreased.

The substance of the above summary is that the characteristics of group 11, made up of wet-site trees, and group 7 (restricted) agree with those of rainfall whereas most of the characteristics of group 10 and group 7 disagree except for correlation with rainfall. Also, *intracorrelation on the wood rises in quality with greater rainfall.*

Obviously, these findings must be translated into a method whereby study of the wood alone can be made to reveal changes in rainfall. Two of the trees from the drier sites (in group 10) for some reason reacted oppositely in comparison with the remainder of the collection and when combined into group 7 (all trees) overbalanced the influence of the remainder save for the one characteristic, average departure from mean variation. It is clear in respect to the Holman Pass trees that agreement of variation among the trees rises with increased rainfall. Such increase in rainfall would be expected to lessen the variation of rainfall within short distances on the ground as it affects growth and thus permit greater agreement among the trees. This is well shown by table 2 especially among groups. Reasoning from a knowledge of rainfall characteristics one can expect average variation to decrease with increase of rainfall.

Therefore, in regard to a study of the wood alone for evidence of rainfall changes, the Holman Pass collection suggests the use of the following methods: (1) the amount of agreement in directional variation, including correlation and trend parallelism, among the trees themselves; (2) the change in average variation, average departure, and average departure from mean variation among growth layers of trees grown under conditions, or in a zone, at least as moist as those for group 11 or for group 7 (restricted).

RÉSUMÉ

In bringing together a résumé of results it is well to recall the several aspects of the study: The site chosen extended from well

within the Transition Zone up into the Canadian; the number of trees sampled was limited to nine; the collection contained trees of four different species and comprised three groups geographically and hypsometrically; the trees, in the field, divided themselves ecologically into two groups, the one (group 10) representing normal water relationships without excess drainage to or from the trees, and the other (group 11) representing slightly above-normal water relationships for the general locality; the samples consisted of increment cores —essentially one radius to represent the entire volume growth of a tree; site factors were judged solely by inspection on the spot; the terrain was mountainous; the nearest rainfall station, Chacon, was 7 miles distant at an elevation intermediate between the highest and lowest trees; and analyses were based on raw (i.e., unsmoothed) data.

The present study brings out many points in summary which are distinctly secondary to the main objectives. In the present stage of investigations of this type, all points, secondary as well as primary, are highly suggestive only. It remains to be determined if the principles and methods here used in the field and in the laboratory are of more general application. Only then can growth-layer sequences be interpreted in the absence of nearby rainfall stations. Obviously, we must know how trees reveal their ecologic information before we can determine what they tell.

Study of growth layers.—1. Cross-dating of high quality is not a necessary prerequisite to the correlation of growth-layer thicknesses and rainfall, and its nearly total absence does not indicate a lack of significant response on the part of the trees to rainfall variations.

2. The presence or absence of high-quality cross-dating does not necessarily constitute the criterion whereby a tree record is included in a group average or excluded from it. Some other criterion should be applied for the elimination of certain growth-layer sequences after the collection is brought to the laboratory, if such elimination is attempted with justification.

3. Partial disagreement among the various trees, growth layer to growth layer, emphasizes a definite localization of site factors to each tree.

4. Disagreement among the trees increased with increasing distance, distance measured in yards rather than in miles.

5. Intergroup correlations (of groups 4, 5, and 9) were merely fair, not at all striking. They show a dual influence of site and distance.

6. In so far as the collection from Holman Pass is concerned, the nature of the species is clearly subordinate to the influence of site.

7. Correlations among different trees and among different groups were distinctly lower for the period 1850-1897 than for the period 1898-1941.

8. A simultaneous comparison of trend among all trees yielded 9 complete agreements among the trees during the 48 years of the period 1850-1897 and 15 during the 44 years of the period 1898-1941.

9. For group 10 (dry sites) average year-to-year variation, average departure, and average departure from mean variation increased whereas for group 11 (wet sites) they decreased for the period 1898-1941 in contrast with the period 1850-1897. However, the average departure of two of the trees in group 10 actually agreed with group 11.

10. The average departure from mean variation of group 7 (restricted) and group 7 itself decreased for the period 1898-1941 in contrast with the period 1850-1897.

11. A study and comparison of the growth-layer sequences emphasize the role of site factors local to each tree and the striking contrast of characteristics between the two periods, 1850-1897 and 1898-1941.

Study of rainfall characteristics.—1. Chacon rainfall was correlated with that of the other six stations for eight different month-intervals. Trend coefficients ranged from 0.61 to 0.99 and ratios of opposed trends from 0.41 to 0.09.

2. No clear-cut pattern emerged from this correlation between Chacon and the other stations. However, the values declined with the presence of summer rainfall and with an increase in the number of months in the month-intervals. Within the area from which rainfall stations were drawn, distance from Chacon made little difference in the variations among the several stations.

3. The average trend coefficient between Chacon and the other stations was approximately 0.89 and the ratio of opposed trends 0.23. If the trees were responding directly to the rain falling at the immediate site, they may be expected to correlate with Chacon rainfall to a degree equaling or slightly exceeding (because of the distance involved) the average of the correlations between Chacon and the other rainfall stations.

4. Correlations among the eight different month-intervals at Chacon ranged from −0.33 to 0.99 for the trend coefficients and from 0.66 to 0.06 for the ratio of opposed trends. Such divergences demanded that tree growth be tested against the full series of month-intervals.

5. If tree growth shows high correlation with a certain rainfall interval, as March-July, and if that interval has high correlation with a second one, as January-August, then tree growth may be expected to show high correlation with the second interval even though part of the rainfall of the longer interval may not influence growth.

6. Within limits, maximum correlation combined with minimum-length month-intervals should be the focus of critical information on the response of trees to rainfall.

7. The average March-July rainfall at Santa Fe was higher during the period 1898-1941 than during the period 1850-1897 and higher during the period 1909-1941 than during the period 1898-1941.

8. Average year-to-year variation, average departure, and average departure from mean variation of March-July rainfall at Santa Fe was less during the period 1898-1941 than during the period 1850-1897.

9. For the contrasted periods 1850-1897 and 1898-1941, the characteristics of the dry-site trees ran counter to those of rainfall whereas those of the wet-site trees ran parallel.

10. When a criterion of conformity, based on average departure, was applied and the two trees not conforming were eliminated, the characteristics of the resultant group 7 (restricted) followed those of rainfall.

Correlation between tree growth and rainfall.—1. Correlations between tree growth and rainfall of Chacon, the nearest station, were highest for the rainfall of the March-July interval of the same year. This is consistent with the principle of maximum correlation with minimum-length month-interval. The next best correlation, with January-August, was also high, but the reason was held to be the rather high correlation between that interval and March-July.

2. The growth of the trees composing the Holman Pass collection correlated directly with the precipitation which fell immediately before and during the season of greatest growth.

3. Correlation between the Holman Pass trees and Chacon March-July rainfall, based on raw (unsmoothed) data, attained the following remarkably high values: a trend coefficient of 0.965 and a ratio of opposed trends of 0.12.

4. The accumulated evidence points rather clearly to the conclusion that the trees respond very nearly 100 percent to fluctuations of rainfall at the immediate site.

5. Correlations between individual trees and Chacon rainfall were lower than those for groups. A few were surprisingly high.

6. The nature of the species appeared to make little difference in the quality of correlations.

7. The variations among the trend coefficients and ratios of opposed trends of individual trees emphasized again the localized influence of site factors on the single tree, the so-called microsite factors.

8. Correlations between tree growth and rainfall of stations other than Chacon gave mixed and rather poor results. Certain regional tendencies remained, but they are of little or no value.

9. Correlations between tree growth and Las Vegas rainfall were higher for the period 1910-1941 than for that of 1893-1941.

10. General correlations between tree growth and Santa Fe rainfall were fair to poor and have little value as regards season-to-season fluctuations. Such results were to be expected in view of the distances involved and the areal differences in rainfall as measured from station to station.

11. The higher the correlations were among the trees themselves, the higher their correlation with rainfall. An increase in amount of rainfall was accompanied by greater agreement among the trees.

12. The most important information brought out by the correlation of tree growth and Santa Fe March-July rainfall for the periods 1850-1897, 1898-1941, and 1910-1941 was this: The quality of the correlations was lowest for the first period and highest for the last. All tree groupings conformed. The amounts of March-July rainfall at Santa Fe showed a similar increase for the three periods.

13. In the above correlations, the trees from the wetter sites showed not only the highest correlations but also the greatest increases.

14. A change in temperature that affected the time of growth initiation in the spring probably shifted the month-interval of rainfall to which the trees responded.

15. Trees from drier sites, as a group, were poor recorders of changes in rainfall characteristics; individually, two out of the four conformed in part to the wet-site group.

16. A summary of changes from the period 1850-1897 to the period 1898-1941 follows:

In March-July rainfall:
- Average variation, average departure, and average departure from mean variation decreased with an increase in average rainfall.

In tree growth:
- Among all trees, internal agreement increased.
- For dry-site trees, group 10, average variation, average departure, and average departure from mean variation increased.
- For all trees, group 7, average variation and average departure increased whereas average departure from mean variation decreased.
- For wet-site trees and group 7 (restricted), average variation, average departure, and average departure from mean variation decreased, thus agreeing with changes in March-July rainfall.

CONCLUSIONS

A study of the Holman Pass collection, which came partly from the Transition and partly from the Canadian Life Zones, permits two general conclusions.

First, the evidence indicates rather clearly that variations in tree growth follow variations of March-July rainfall from year to year very nearly 100 percent at the immediate site of the trees.

Second, the evidence strongly suggests that changes of internal agreement among the trees and changes of average variation, average departure, and average departure from mean variation can be used as a method to reveal changes in rainfall through the years where amount of rainfall, and hence derived soil moisture, approximately equals that present at the location of the dominant members of the Holman Pass collection.